

Environmental Justice

RESEARCH ROADMAP



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Authors and Contributors

Andrew M. Geller

Environmental Justice Research Roadmap Lead
Sustainable and Healthy Communities Research Program

Contributors

Maggie Breville

Office of Research and Development,
National Central for Environmental Research

Emily Eisenhauer

Kathy Sykes

Office of Research and Development,
Sustainable and Healthy Communities Research Program

Florence Fulk

James Quackenboss

Valerie Zartarian

Office of Research and Development,
National Exposure Research Laboratory

Fred Hauchman

Ed Washburn

Office of Research and Development,
Office of Science Policy

Annie Jarabek

Office of Research and Development,
Human Health Risk Assessment Research Program

Charles Lee

Office of Enforcement and Compliance Assurance

Mary Manibusan

Sharon Oxendine

Office of Chemical Safety and Pollution Prevention

Emily Snyder

Office of Research and Development,
Homeland Security Research Program

Kathleen Williams

Office of Research and Development,
National Health and Environmental Effects Research Laboratory

Executive Summary

Many studies have established that sources of environmental hazards are disproportionately located in communities that have a majority population of people of color, low-income residents, or indigenous peoples. Studies also show that these population groups often experience higher exposures to environmental hazards associated with the places where they live, work, and play. Additionally, these population groups tend to be most burdened with adverse health conditions that either have environmental triggers or affect similar physiological systems as environmental pollution, such as cardiovascular disease, preterm birth, low birth weight, and asthma.¹ Finally, America's overburdened communities are, in many cases, those that are least prepared for potential impacts from environmental stressors associated with climate change such as extreme weather emergencies or heat stress.

The *Environmental Justice Research Roadmap* describes the interface between environmental justice and science, and outlines opportunities that exist in the link between environmental equity and technology. Science is needed to inform the U.S. Environmental Protection Agency's (EPA's) considerations of environmental justice in its policies and its regulatory analyses and in the implementation of its programs. **The research included in this Roadmap will provide the scientific basis to improve EPA's and other stakeholders' ability to take actions to mitigate and prevent health disparities from environmental conditions and pollution.** Newly developed software tools will provide access to science and technology to facilitate community-engaged decision-making to help build healthy, safe, and sustainable communities and Tribes. Further, the research described here will provide a scientific and technological basis to help the Agency and decision-makers at State, Tribal, and local levels ensure the equitable distribution of the benefits of the built and natural environments.

This Research Roadmap focuses on four science challenges:

1. **Developing decision-support tools for identifying and prioritizing concerns, assessing cumulative impacts, and evaluating mitigation options.** This challenge includes the development of decision-support tools and science, including citizen science, to ensure meaningful engagement and to acknowledge community ownership or investment in the process of research, data collection, and development of solutions. This research and development is used in problem formulation and scoping, for screening-level assessments, and to improve information access, evaluate options, and inform decision-making.
2. **Improving our understanding of environmental health disparities and developing methods and data for assessing cumulative risks.** This challenge includes research to reduce health risks and mitigate the incidence and prevalence of environmental health disparities in overburdened communities. This includes scientific understanding and supporting metrics to support the consideration of cumulative risk of multiple contaminants and nonchemical or community stressors in risk assessments.

¹ Summarized in EPA (2016b) and Morello-Frosch, et al. (2011).

3. **Supporting Tribal sustainability and well-being.** This challenge includes science to support the use of traditional ecological knowledge, facilitate the characterization and mitigation of environmental conditions that place heritage diets and other cultural practices at risk, and support the environmental health and well-being of Tribal nations.
4. **Characterizing climate justice.** This challenge includes research to characterize community-scale vulnerability and resilience factors and risk of health disparities resulting from environmental stressors such as extreme weather conditions, drought, flooding, or other results of changes in precipitation, heat stress, sea level rise, and changes in natural benefits (ecosystem services).

This research is included in the [FY16–19 Strategic Research Action Plans](#) that guide the Office of Research and Development’s (ORD’s) research. The EJ Research Roadmap is a key element in EPA’s [EJ 2020 Action Agenda](#).

This Roadmap also recognizes that gaps remain in EPA’s approach for advancing science to address EJ issues. These include:

- Understanding the interactions of the built, natural, and social environments with human biology that result in health disparities.
- Incorporating these interactions into cumulative assessments.
- Researching the equitable distribution and quality of ecosystem services; social and political influences on the generation, distribution, and valuation of ecosystem services; and impacts on health promotion.
- Developing standardized methods and metrics for EJ analysis, including exposure assessment.
- Increasing social science capacity in EPA’s ORD and integrating social science with natural, physical, and other environmental science.
- Increasing direct community engagement in the development of the Agency’s scientific agenda and priorities.
- Assessing outcomes both directly related to the usability of the science and tools developed by EPA and longer-term outcomes resulting from voluntary or regulatory actions designed to promote health and reduce environmental inequities.
- Continuing to build scientific and technical capacity in overburdened communities to enhance community capacity to engage meaningfully in the development of environmental rules and other decisions that affect communities.

I. Introduction

This *Environmental Justice Research Roadmap* describes the interface between environmental justice and science and outlines opportunities for scientific research that exist in the link between environmental equity and technology. The research presented here is included in the [Fiscal Year 2016–2019 Strategic Research Action Plans](#) (StRAPs) that guide research in the U.S. Environmental Protection Agency’s (EPA’s) Office of Research and Development (ORD) through 2019. The research and development needed to support decisions that advance environmental justice (EJ) cross traditional scientific disciplines. This Roadmap outlines specific strategies for uniting ORD programs and expertise into a seamless, efficient overall research portfolio.

The EJ Research Roadmap is a key element in the EPA’s developing [EJ 2020 Action Agenda](#). The Roadmap represents a significant body of research (some in progress, some proposed) that recognizes the importance of near-source exposures and the demographics of those exposed. It seeks to determine whether the burden of environmental health risk is evenly distributed across all Americans or whether some communities carry the preponderance of that risk, and why. ORD’s inclusion of research to address overburdened groups and communities was accelerated by engagement with advisory groups and the development of a science plan in EPA’s [Plan EJ 2014](#) (EPA, 2011).

Science to Support EPA’s EJ 2020 Action Agenda

The EJ 2020 Action Agenda identifies steps the Agency will take over the next few years to integrate environmental justice into everything it does, cultivate strong partnerships that improve on-the-ground results, and chart a path forward for reducing disparities in the Nation’s most overburdened communities.

ORD research related to environmental justice will strengthen the scientific foundation for actions at the Agency, Tribal, State, local, and community levels to address environmental and health inequalities in overburdened populations and communities. This goal will be attained by using fundamental and community-based research approaches to develop scientific understanding, guidance, decision tools, and scientific information to support decision-making. ORD has identified four core research areas—termed “science challenges”—through which critical contributions for addressing environmental justice can be made:

1. Developing decision-support tools,
2. Improving our understanding of environmental health disparities and developing data and methods for assessing cumulative risk;
3. Supporting Tribal science; and
4. Characterizing climate justice.

For each science challenge, this Roadmap presents key science questions, identifies important research products, and summarizes how ORD’s ongoing and planned research will address the challenge.

A. Background

In 1994, President William J. Clinton issued Executive Order (EO) 12898 in which he declared “each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.” The President issued this order in recognition of the racial and economic disparities in the locations of toxic sites and their potential impacts on adjacent communities. These disparities had fueled the birth of the environmental justice movement more than a decade earlier when the civil rights and environmental movements came together to protest the locating of a waste site for soil contaminated with PCBs (polychlorinated biphenyls) in a predominantly African-American community in North Carolina (Table 1).

The Agency’s mandate to pursue environmental justice is rooted in the specific provisions² of EO 12898 regarding research related to the health and environment of people of color and low-income populations, specifically noting the importance of developing the science to assess multiple and cumulative exposures. Table 1 lists additional milestones in the development of EJ programs at EPA. EPA’s [Technical Guidance for Assessing Environmental Justice in Regulatory Analysis](#) (EPA, 2016b) and [Guidance on Considering Environmental Justice during Development of Regulatory Actions](#) (EPA, 2015b) contain excellent descriptions of the role of science, impact, and risk assessment in regulatory analysis and EPA’s regulatory authority with respect to environmental justice.

Table 1. Key Events in the Development of Environmental Justice Programs at EPA		
Year	Event	Content
1982	Warren County, NC Landfill for PCBs	Linking of environmental and civil rights movements, resulting in civil disobedience action drawing attention to environmental racism; more than 550 protesters were arrested
1987	Report by Commission for Racial Justice United Church of Christ	Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Wastes Sites ; recognized racial and economic disparities in hazardous waste siting
1992	Report by EPA Environmental Equity Workgroup	Reducing Risk in all Communities (1992) recognized that environmental risks are often greater for low-income and minority communities
1992	Formation of EPA Office of Environmental Equity/Justice	EPA’s Office of Environmental Equity established in November 1992; name changed to the Office of Environmental Justice in 1994
1993	Formation of National Environmental Justice Advisory Council (NEJAC)	The National Environmental Justice Advisory Council , a Federal advisory committee to EPA, provides advice and recommendations about broad, crosscutting issues related to environmental justice from all stakeholders involved in the EJ dialogue
1994	Issuance of Presidential EO 12898 <i>Federal Actions To Address Environmental Justice in Minority Populations</i>	EO 12898 focused Federal attention on environmental and human health conditions in communities of color and low income with the intention of achieving environmental justice; established the expectation that Federal agencies use existing regulatory statutes to address environmental justice, including the Civil Rights Act of 1964 and the National Environmental Policy Act of 1969

² [Section 1-103](#) and [Section 3-3](#) of the Executive Order outline goals for research, data collection, and analysis specific to environmental justice.

Table 1. Key Events in the Development of Environmental Justice Programs at EPA		
Year	Event	Content
1999	National Academy of Sciences report Toward Environmental Justice: Research, Education, and Health Policy Needs	Institute of Medicine report on environmental justice made strong recommendations to improve the science base, involve the affected population, and communicate the findings to all stakeholders
2004	EPA: Toolkit for Assessing Potential Allegations of Environmental Injustice	Provides a conceptual and substantive framework for understanding the Agency's EJ program; presents a systematic approach with reference tools and indicators for use in assessing and responding to potential allegations of environmental injustice or in preventing injustices from occurring; includes the Guzy memo (2000) that described the EPA statutory and regulatory authorities under which EJ issues may be addressed in permitting
2010	EPA Symposium on the Science of Disproportionate Environmental Health Impacts	Science from inside and outside EPA to address environmental justice including indicators, indices, cumulative assessment, and information access tools
2014	Development of EPA Plan 2014 EJ	Strategy and implementation plans to protect the environment and health in overburdened communities; empower communities to take action to improve their health and environment; and establish partnerships with local, State, Tribal, and Federal organizations to achieve healthy and sustainable communities
2014	EPA FY2014–2018 EPA Strategic Plan	EPA's EJ-related research, along with the activities of other EPA offices, support the Administrator's commitment to ensuring that all communities have the same degree of protection from environmental and health hazards
2014	NEJAC recommendations for research	NEJAC released the report, Recommendations for Integrating Environmental Justice into the EPA's Research Enterprise
2015	EPA final Guidance on Considering Environmental Justice during Development of Regulatory Actions	EPA's guide for determining when environmental justice should be considered during the Action Development process when developing regulations; includes strategies and techniques for meaningful involvement and screening-level assessments to identify potential EJ concerns
2015	Active development of EJ 2020 Action Agenda	EJ 2020 will build on the foundation established through EPA's Plan EJ 2014 and expand that work through commitments that will continue through the next five years
2016	EPA publishes Technical Guidance for Assessing Environmental Justice in Regulatory Analysis	Provides technical guidance to help analysts evaluate potential EJ concerns associated with EPA regulatory actions; based on currently available, scientifically appropriate risk assessment and regulatory analysis methods

The mission of EPA is to protect human health and the environment. The Agency works with urban, rural, and economically disadvantaged communities to ensure that everyone—regardless of age, race, economic status, or ethnicity—has access to clean water and clean air and the opportunity to live, work, learn, and play in healthy communities (EPA, 2014a). EPA’s goal is not only to provide protection for the general population, but also to minimize inequities in health risks, environmental quality, and the distribution of ecosystem services (nature’s benefits) to overburdened communities.

Critical Definition: Environmental Justice

EPA defines environmental justice as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” (EPA, 2016b).

Critical Definition: Overburdened

“Overburdened” describes ethnic minority, low-income, Tribal, and indigenous populations or communities in the United States that potentially experience disproportionate environmental harms and risks due to exposures or cumulative impacts or greater vulnerability to environmental hazards. This increased vulnerability may be attributable to an accumulation of both negative and lack of positive environmental, health, economic, or social conditions within these populations or communities, including the inability to participate meaningfully in the decision-making process (Plan EJ 2014).

EPA’s EJ efforts seek to protect the health and environment of overburdened communities, support these communities in taking action to improve their own health and environment, and build partnerships for improving community health and long-term well-being (EPA, 2016a). The Agency aims to conduct community-engaged research to support improved integrated assessments considering multiple contaminants and life stressors. Ideally, this work integrates social and physical sciences aimed at improving our understanding of environmental and health inequalities in overburdened populations and communities in the United States and taking appropriate actions to eliminate disproportionate impacts (EPA, 2011). Technological development is focused on enhancing community stakeholder access to scientific information to inform decision-

making with the goal of improving the ability to characterize environmental conditions and identify, assess, and compare available options to reduce potential health and environmental impacts. Under [Plan EJ 2014 \(EPA, 2011\)](#), EPA committed to continue building the strong scientific foundation to support environmental justice and conduct disproportionate impact analysis, particularly methods and supporting scientific information to characterize and assess cumulative impacts appropriately. This research has been formally included in the [FY16–19 StRAPs](#) that guide ORD research through 2019. EPA’s [Fiscal Year 2014–2018 EPA Strategic Plan \(EPA, 2014a\)](#) “recognizes (that) environmental justice, children’s health, and sustainable development are all at the intersection of people and place... Throughout all our work to achieve more livable communities, EPA is committed to ensuring we focus on children’s health and environmental justice.” The [EPA Strategic Plan](#) also captures the Agency’s long-standing commitment to strengthen human health and environmental protection in Indian country and

increase Tribal capacity to establish and implement environmental programs. EPA is striving for an outcome that has been defined as Just Sustainabilities: Ensuring a better quality of life for all, as defined in different community contexts, now and into the future, while living within the limits of supporting ecosystems (Agyeman et al., 2003). Environmental justice, disadvantaged communities, and Tribal issues are explicitly addressed in four of EPA's five media and enforcement-based strategic goals and in two of its cross-agency strategies; research needs for these goals are addressed across ORD's six National Research Programs. In recognition of this, ORD has identified environmental justice as a crosscutting research area.

B. Problem Statement

Many studies have established that sources of environmental hazards often are located and concentrated in areas having majority populations of people of color, low-income residents, or indigenous peoples (e.g., Agyeman, et al., 2016; Bullard, 1994; Bullard, et al., 2008; Cutter, 2003; Maantay, 2001; Mohai, et al., 2009; Mohai and Saha, 2015b; Ringquist, 2005). Studies also show these population groups often experience higher exposures to environmental hazards associated with the places where they live, work, and play, often in conjunction with additional social and economic stressors (Morello-Frosch, et al., 2011). Additionally, these population groups tend to be most burdened with adverse health conditions that either have environmental triggers or affect similar physiological systems as environmental pollution, such as cardiovascular disease, preterm birth, low birth weight, and asthma (EPA, 2016b; Morello-Frosch, et al., 2011). Finally, America's overburdened communities are, in many cases, those least prepared for potential impacts from environmental stressors associated with climate change such as extreme weather emergencies or heat stress (Shi, et al., 2016). Addressing environmental justice requires a public health model of prevention and targeted action to mitigate disproportionate risk and health disparities from environmental conditions and pollution and to promote health and well-being (Bullard, 1993).

The goal of ORD research addressing environmental justice is to strengthen the scientific foundation for actions at the agency, State, Tribal, local, and community levels that address environmental and health inequalities in overburdened populations and communities. EPA needs science to be able to consider environmental justice fully in its policies, regulatory analyses, and program implementation, including those programs EPA administers directly, delegates to States or Tribes, or effects through voluntary efforts or community-level action. Needed research includes examining exposure to overburdened communities, factors affecting health disparities, and the equitable distribution of the benefits of the built and natural environments. Research translation and technical support and development are needed to provide access to science and technology to facilitate community-engaged decision-making to help build healthy, safe, and sustainable communities and Tribes.

C. Purpose

The EJ Research Roadmap assembles the research from across ORD that is designed to address medium-specific and multimedia cumulative exposures and impacts, to identify and remediate conditions, and to build capacity for community-engaged action in overburdened communities—all in the context of the

community or social environment in which people live, work, and play (Olden, et al., 2015). This Roadmap describes the interface between environmental justice and science and outlines opportunities presented in the link between environmental equity and technology. The EJ Research Roadmap highlights EPA’s role in science to address environmental justice. This Roadmap and the EJ2020 Action Plan (EPA, 2016a) will help facilitate greater coordination and integration of EJ research efforts of ORD and the Agency.

The research inventoried and described in this Roadmap does not comprise a separate, independent research program. Rather, it is conducted as part of ORD’s six National Research Programs and will serve to inform further research direction by identifying research gaps. EJ-related research promotes sustainable, healthy communities by providing state-of-the-science information, tools, and decision processes that help characterize environmental and health inequities and lead to their mitigation. The Roadmap also emphasizes research efforts that engage and work with community stakeholders to reduce disproportionate environmental exposures and health impacts, ultimately promoting equitable access to sustainable and healthy environments for all.

Critical Definitions: Health and Well-Being, Sustainability

The World Health Organization defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1948).” ORD’s Sustainable and Healthy Communities research program emphasizes this definition in its Strategic Research Action Plan (StRAP): Well-being is defined broadly and includes human health and safety, continued access to the benefits provided by ecosystem services, and economic security and resilience, now and in the future.

*This definition is central to SHC’s working definition of **sustainability** as the long-term well-being that emerges from a resilient economy existing within a healthy society dependent on an intact, functioning environment.*

The EJ Research Roadmap serves to communicate to EPA’s Program and Regional Office partners and to EPA’s external stakeholders (State and local agencies, Tribal organizations, public health and community groups) how ORD is integrating EJ-related scientific research across its National Research Programs. ORD research has been and will continue to be instrumental in supporting Agency rulemaking and policy decisions to reduce environmental health disparities in communities. Research findings will provide the Agency, State and local governments, and other community stakeholders with scientific information that will inform decisions to improve environmental equity regarding public health and environmental quality. Environmental equity includes ensuring access for all people to nature’s benefits that promote health and well-being such as those afforded by, e.g. access to green space, urban tree arbors, clean water, and

features of the environment that provide natural hazard mitigation, reducing environmental exposures and accompanying health impacts.

ORD staff developed this Roadmap in consultation with staff from EPA Regional and Program Offices, including the Office of Environmental Justice. It responds to recommendations on the planning and

implementation of research addressing EJ concerns received from key advisory committees: ORD’s [Board of Scientific Counselors](#) (2015), the [National Environmental Justice Advisory Council](#) (NEJAC, 2014), and the [National Advisory Council on Environmental Policy and Technology](#) (NACEPT, 2012). Additional input comes from the [Children’s Health Protection Advisory Committee](#) (CHPAC, 2013) and national strategies such as [Healthy People 2020](#) (DHHS, 2010).

[Section 3-3](#) of EO 12898 emphasizes including at-risk populations in environmental health research, identifying multiple and cumulative exposures, and engaging overburdened groups in the development and design of research that affects their communities. [Healthy People 2020](#), along with recent guidance from [NEJAC](#) and [CHPAC](#), includes recommendations for research on the social determinants of disease and how psychosocial stressors in overburdened communities could modify sensitivity to the effects of pollution and

Healthy People 2020 set the elimination of health disparities and achieving health equity as top national priorities. Its focus on health equity calls for addressing the determinants of health that put particular groups within the general population at potential disproportionate risk (DHHS, 2010).

result in health disparities. Understanding the contribution of the environment to health disparities promotes the development of policies and interventions that provide primary prevention and helps improve resiliency at the individual and community levels. NEJAC also recommended that EPA characterize and identify or map communities that are potentially vulnerable to the impacts of climate change (e.g., based on geographic and demographic vulnerability) and analyze and measure socioeconomic, racial, or ethnic disparities associated with various adaptation and mitigation options. NACEPT’s recommendations focus on technologies for detection and assessment, communications, and remediation solutions. These guidance documents, advisory reports, and strategic plans emphasize the importance of community engagement and meaningful involvement in addressing environmental health and well-being.

II. Research Scope

A. Expanded Problem Statement

In June 1992, EPA issued its first report that recognized that environmental risks are often greater for low-income communities and especially for communities of color, *Reducing Risk in All Communities* (EPA, 1992) (see Table 1). This report followed on the United Church of Christ (1987) report, which found race to be the most important variable in predicting where commercial hazardous waste facilities were located in the United States. This finding has since been confirmed and extended by many reports, which have noted that racial disparities in placing locally unwanted land uses persist (e.g., UCC, 2007; Ringquist, 2005; Mohai and Saha, 2015b). The impacts on citizens in these communities are influenced not only by differential exposures due to close proximity to sources of harmful chemicals or toxicants, but also by nonchemical stressors. Communities also can suffer from inadequate physical and economic infrastructures: poor housing, lack of transportation, insufficient healthy foods, limited access to natural amenities such as green spaces or parks and to medical care, and inadequate water systems. Further,

exposures to multiple environmental contaminants and nonchemical stressors can combine to induce adverse impacts on health or result in greater, cumulative impacts. This complexity places issues associated with environmental justice among the “wicked problems” that EPA will face during the next decade. These problems are not only complex, affected by many factors of various spatial and long temporal scales, and difficult to define, but also might be socially complicated, without a clear solution or endpoint, and extend beyond the understanding of one discipline (NRC, 2012). Research to address these issues will require a combination of qualitative, semiquantitative, and quantitative approaches, including collaborative approaches from among the natural, physical, and social sciences.

The four science challenges listed below address multiple facets of environmental justice (Agyeman, et al., 2016; Cook and Swyngedouw, 2012; Shi, et al., 2016; Schlosberg, 2004). Science and technology to enhance community engagement addresses issues of *meaningful involvement and procedural justice*, that is, the need for fairer and more democratic decision-making processes and the involvement of overburdened communities in the process. Science to reduce disparities addresses *distributional justice*, that is, the need for adverse environmental exposures and impacts not to be concentrated in, or nearby, overburdened communities. Citizen science, tools to enhance information access, and an increased emphasis on equitable distribution of natural amenities addresses a *justice of capabilities*, that is, the need to create the capabilities necessary for supporting a healthy, functioning community (Cook and Swyngedouw, 2012). Research that recognizes the long-term conditions in neglected, devalued neighborhoods and the need for their ongoing sustainability addresses *recognitional justice*, that is, the need for recognition of, and respect for, the disadvantaged communities that suffer from environmental injustice (Agyeman, et al., 2016; Cook and Swyngedouw, 2012; Anguelovski, et al., 2016; Schlosberg, 2004). These challenges also capture critical areas of focus that Agency advisory groups, as described above, have identified or that have emerged as our understanding has improved of the stressors associated with climate change and their interaction with environmental exposure, sensitivity, and adaptive capacity (USGCRP, 2016).

Meaningful involvement and procedural justice, distributional justice, justice of capabilities, and recognitional justice collectively recognize the need to

1. provide access to science-based, comprehensive decision-support tools that engage community members and other stakeholders for building healthy, safe, and sustainable communities;
2. provide the essential understanding of the drivers of exposure and health disparities to be able to take regulatory and other actions to prevent these disparities;
3. fulfill EPA’s trust responsibilities with respect to federally recognized Tribes; and
4. address the impacts of stressors associated with climate change, such as extreme heat, flooding, drought, extreme weather, and vector-borne disease that could interact with the exposure, health conditions, and adaptive capacity in overburdened communities.

This Research Roadmap focuses on four science challenges:

1. **Developing decision-support tools for identifying and prioritizing concerns, assessing cumulative impacts, and evaluating mitigation options** – Development of decision-support tools and science, including citizen science, to ensure meaningful engagement and acknowledge community ownership or investment in the process of research, data collection, and development of solutions. This research and development is used in problem formulation and scoping, screening-level assessments, and improving information access, evaluating options, and informing decision-making. This research reflects ORD’s long-standing commitment to provide research and technical support to remediate existing contaminated sites and to develop materials management approaches that help avoid creating new ones.
2. **Improving our understanding of environmental health disparities and developing methods and data for assessing cumulative risks** – Research to understand and reduce health risks and to mitigate the incidence and prevalence of environmental health disparities in overburdened communities. This research includes developing scientific understanding and metrics to support the consideration of cumulative risk of multiple contaminants and nonchemical or community stressors (see Figure 2) in risk assessments.
3. **Supporting Tribal sustainability and well-being** – Science to support the use of traditional ecological knowledge, facilitate the characterization and mitigation of environmental conditions that place heritage diets and other cultural practices at risk, and support the environmental health and well-being of Tribal nations.
4. **Characterizing climate justice** – Characterization of community-scale vulnerability and resilience factors and cumulative risk of health disparities resulting from environmental stressors, for example, extreme weather conditions, drought, flooding, or other results of changes in precipitation, heat stress, sea level rise, and changes in natural benefits (ecosystem services).

The EJ Research Roadmap addresses research on impact assessment, screening-level tools, and cumulative risk assessment (CRA). Cumulative impact assessments and CRAs are distinguished by such factors as the amount and quality of data available, the level of scientific rigor and quantitation required, and whether the application is for nonregulatory or regulatory purposes (EPA, 2016a). The National Academy of Sciences noted the importance of the distinction between cumulative impacts and risks in its landmark report, *Science and Decisions: Advancing Risk Assessment* (NRC, 2009). Cumulative impact assessments use a range of qualitative and quantitative information to characterize a problem or establish priorities for action by local, State, Tribal, or national decision-makers. Such assessments, which include health impact assessments (HIAs), are of particular value for advancing policies to promote the health and well-being of overburdened communities. CRAs, by contrast, are typically more analytically complex, quantitative assessments of the combined risk to health or the environment from multiple stressors. Decisions made at the Federal level to establish standards for environmental contaminants, for example, would require the more rigorous assessments. Due to the special data and methodological requirements of CRAs, this approach currently is less applicable than cumulative impact assessments to local decision-making, although a CRA could provide needed information to inform one or more objectives of a structured decision process like an HIA.

The research and development described in this Roadmap can be applied to analyses that provide useful information about how policy options under consideration might affect distribution of risks across population groups of concern and communities. Cumulative impact and risk assessment, along with life-cycle assessment of chemicals and materials; acquisition of data on critical health stressors and promoters in the built, natural, and social environments; and differential exposures and outcomes are all part of science-informed environmental decision-making and policy (Figure 1). This iterative process starts with effective planning and scoping, which in turn drives subsequent steps of problem formulation, data acquisition, modeling and analysis, and effective translation and communication to assess the implications of decisions (NRC, 2012). The iterative nature of this process means that assessments and approaches necessarily will be fit for the purpose of the decision at hand (“fit-for-purpose”), considering the context and use of the final results (EPA, 2016b).

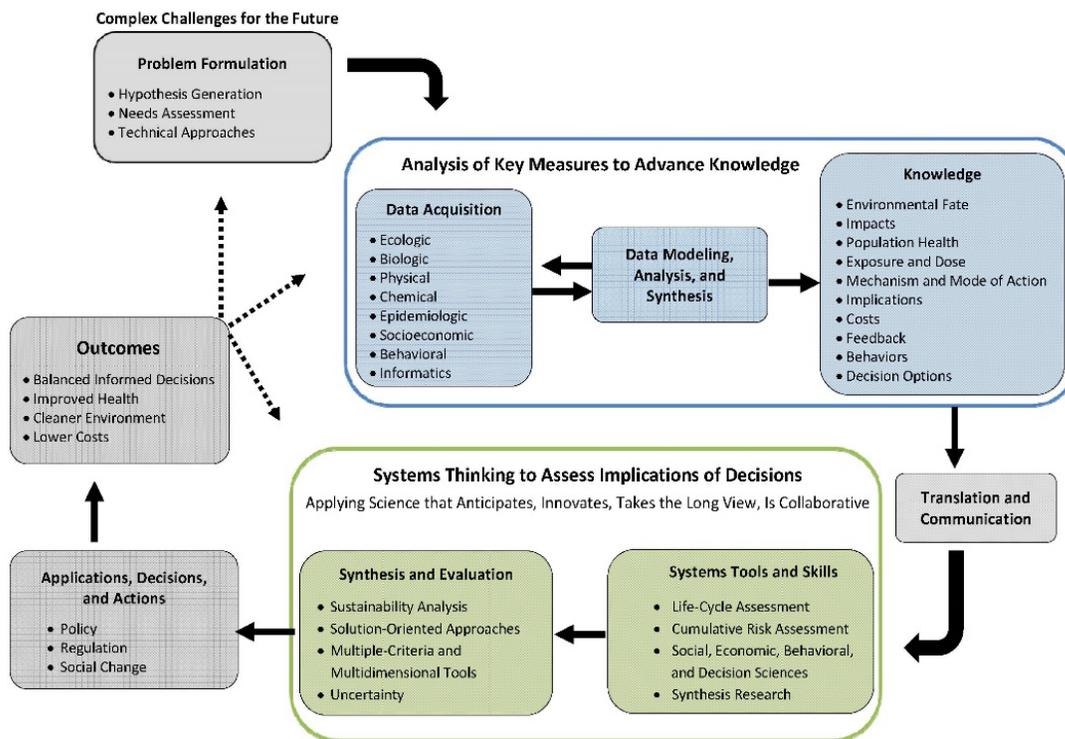


Figure 1. Framework for enhanced science for environmental protection describes the iterative process of science-informed environmental decision-making and policy (NRC, 2012).

The science challenges in this Roadmap are not mutually exclusive because they contain components that address related aspects as ORD moves toward a systems approach to environmental justice. In recognition of this overlap, some of the same science questions pertain to multiple challenges.

B. Scientific Challenges and Key Research Topics

Developing Decision-Support Tools for Identifying and Prioritizing Concerns, Assessing Cumulative Impacts, and Evaluating Mitigation Options

EPA recognizes that research to serve communities will have the greatest impact when it addresses problems formulated at the community stakeholder level and when it is conducted, if possible, through participative and collaborative studies. Such a transdisciplinary approach is rooted in community-engaged research. It builds on community expertise and places the focus on the end user of the science, while providing opportunities for the community to build capacity. These opportunities help ensure meaningful engagement in the processes of research, data collection, and development of solutions—and acknowledge community ownership of, or investment in, that process (Heany, et al., 2007).

Research addressing the challenge of decision support and community engagement includes the continued, evolving development of decision processes such as HIAs and other structured decision approaches that allow for translation of scientific information into objectives that are meaningful to both community members and technical experts. These approaches incorporate a community's values into the decision process and ideally allow science to be considered together with other factors, such as job creation, demographics, environmental quality, and land use or transportation issues, in decisions that affect communities. For EPA, this research and research process is designed to increase community engagement and ensure that the Agency provides access to the best science available and facilitates its application to decision-making and generating solutions for overburdened communities.

Additional research under this challenge includes developing and applying tools that provide access to relevant community-scale data and mapping or other visualization tools. Screening-level assessment tools are included, which can potentially be used to evaluate various decision scenarios. Finally, this research topic includes citizen science, such as environmental monitoring and GIS (geographic information system) mapping. In 2015, EPA charged NACEPT to comment on [strategic directions for using citizen science](#) (EPA, 2015a). In this charge, EPA noted, "Citizen science advances environmental protection by helping communities understand local problems and collect quality data that can be used to advocate for or solve environmental and health issues." The White House Office of Science and Technology Policy recently issued a memorandum that directs agencies to take specific actions to advance citizen science and crowdsourcing, emphasizing public participation and making it easy for people to find out about and join in these projects. In addition, to fulfill a commitment made in the 2013 Open Government National Action Plan, the U.S. government is releasing the first-ever Federal Crowdsourcing and Citizen Science Toolkit to help Federal agencies design, carry out, and manage citizen science and crowdsourcing projects. Early successes of citizen science in addressing community environmental issues include water and air monitoring approaches (Heany, et al., 2011; EPA, 2016c). The incorporation of citizen science, especially that which uses the new generation of environmental monitoring tools, into community-engaged research is an exciting new research area for ORD.

Finally, research on environmental justice recognizes social inequities in the geographic distribution of environmental hazards, including uncontrolled hazardous waste sites; hazardous waste treatment,

storage, and disposal facilities; leaking underground storage tanks; and other locally unwanted land uses (UCC, 1987; UCC, 2007; Bullard, et al., 2007; Wilson, et al., 2013). The remediation and restoration of contaminated sites in America's communities is a long-standing goal of EPA (EPA, 20140a). Scientific research and technical support to identify, remediate, and restore contaminated sites in our communities also is a strategic EPA goal and a primary focus of ORD's Sustainable and Healthy Communities research program (SHC) (Bessler and McKernan, 2015; EPA, 2015c). SHC's research project on contaminated sites and sediments addresses the importance of preventing human exposure to contaminants, with a focus on ensuring that groundwater quality meets drinking water standards (EPA, 2015c). SHC recognizes that remediation of contaminated sites (or potentially contaminated sites, such as brownfields) and their restoration for use as natural areas or for commercial or other uses can be important first steps for mitigating EJ concerns. SHC research addresses the broad range of issues involved in contaminated sites research: contaminated sites and sediments, environmental releases of oils and fuels, and sustainable materials management. Below, research that is specifically focused on EJ goals is described.

Key science questions:

1. How can research to support decision-making at the Regional, State, and Tribal levels be better translated so that it is accessible, useful, and transparent?
2. How can overburdened communities be empowered to better characterize problems linked to the environment and create solutions that ensure equitable distribution of the benefits from community decisions?
3. How can indicator approaches assist in better understanding the interrelationships between social determinants of health, other nonchemical stressors, chemical agents, and the natural environment—with particular emphasis on place-based contexts and potential for decision-making?
4. How can EPA use community-engaged research to understand cumulative exposures and risks and health disparities, and examine scenario-specific case studies to explore implementation of cumulative impact or risk assessment?
5. How can contamination, from single or multiple sources, be characterized effectively and remediated optimally to protect community public health and make land available for safe reuse?

Improving Our Understanding of Environmental Health Disparities and Developing Methods and Data for Assessing Cumulative Risks

EPA research will help in understanding and identifying ways to prevent health disparities that result from environmental conditions and pollution in overburdened populations and communities. This effort includes developing science and approaches to problem formulation to assess cumulative risk from exposure to chemical and nonchemical stressors. It also includes promotion of health and well-being by considering the built and natural environments, including access to nature's benefits (ecosystem services).

Previous research has focused primarily on disproportionate exposure to chemicals and their associated adverse health effects. Expanding this area is needed, however, to understand how social determinants of health—the conditions in which people are born, grow, live, work, and age—together with environmental pollutants and poor environmental quality, can contribute to inequities in health and well-being (Figure 2 and Figure 3). Social determinants of health include such factors as access to affordable healthy food, potable water, green space, safe housing, clean air, and supportive social networks (CHPAC, 2013; EPA, 2016b; deFur et al., 2007). Within the context of social determinants of health, environmental determinants—comprising natural, built, and social environments—stand out as critical for reducing and preventing health disparities because they are amenable to intervention and prevention strategies. Thus, environmental influences are not limited to physical, chemical, or biological agents and natural amenities, but also include social and economic stressors, institutional processes, and resiliency factors. Because environmental stressors often co-occur, a key need is to understand how they act in combination with one another and how they combine with non-environmental stressors. Research is needed to understand the contributing factors and the potential impact they have on communities and individuals so that it can be factored into decisions.

Improved health and well-being are the critical endpoints for this research. Health impacts documented to show disparities in the incidence and severity of disease between socioeconomic and racial or ethnic groups include adverse birth outcomes, cognitive deficits, effects related to growth and metabolism (obesity, diabetes, high blood pressure, cardiovascular disease), and respiratory health impacts (asthma) (e.g., Morello-Frosch, et al., 2011). Well-being is defined broadly; it includes human health and safety, continued access to the benefits provided by ecosystem services, and economic security and resilience, now and in the future.³

This science challenge emphasizes understanding the interactions among biological, social, spatial, and environmental factors and how they contribute to disproportionate risk. Toward this end, laboratory and community-based studies are designed to evaluate the extent to which these various factors contribute to disproportionate risks and health disparities in overburdened communities. This research is prerequisite to understanding the causal bases of adverse effects due to cumulative exposures for informed and effective EPA and community-based decisions and interventions. ORD's Human Health Risk Assessment research program (HHRA) has made as its goal to move beyond traditional risk assessment methods to integrate and evaluate impacts of chemical and nonchemical stressors on the environment and human health (Figure 2). Reaching this goal will be aided by making causal links between the nonchemical stressors on the left of this figure and the realization of adverse health effects through biological pathways on the right.

³ This definition is included in the ORD's [Sustainable and Health Communities Research Program Strategic Research Action Plan FY16–19](#).

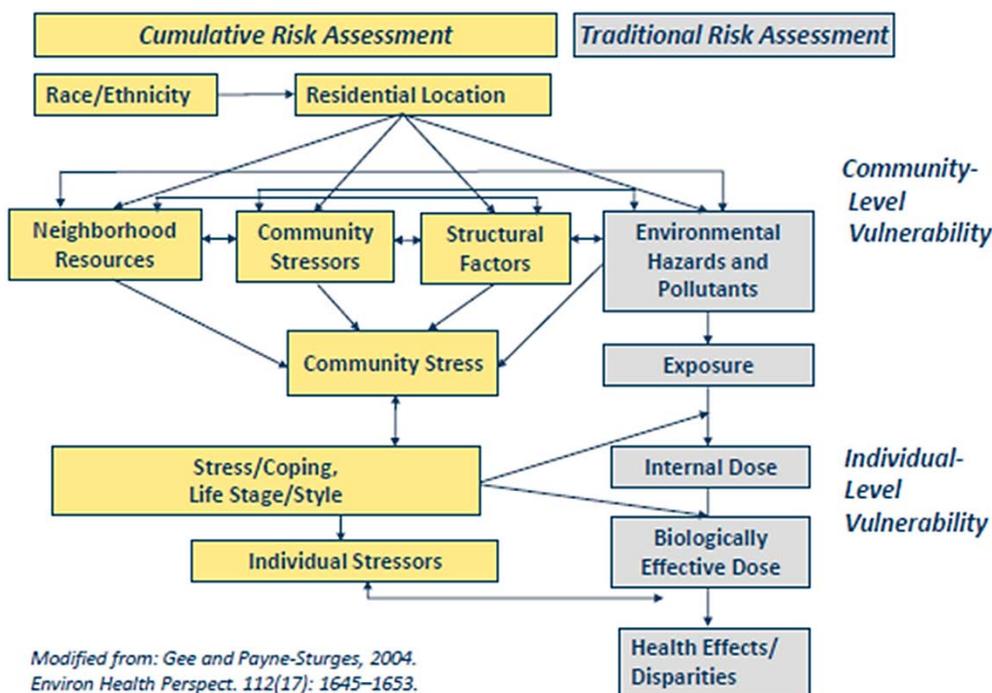


Figure 2. Conceptual map of the interaction between traditional risk assessment, focused on biological dose and adverse outcome pathways emphasized by the Chemical Safety for Sustainability research program, and community-scale contributors to cumulative risk assessment needed to address environmental health disparities.

Key science questions:

1. What interactions between environmental exposures and social, natural, and built environmental systems, conditions, and policies result in unequal adverse environmental health conditions among diverse overburdened population groups, Tribes, communities, neighborhoods, and individuals? How can this understanding be applied to CRA?

What are the key social determinants related to vulnerability and environmental public health for high priority public health outcomes such as poor birth outcomes, cognitive deficits, cardiovascular disease, obesity, diabetes, asthma?
2. What causal links can be made between chemical and nonchemical stressors and potential biological adverse outcome pathways and mechanisms such as epigenetics for the purposes of CRA and the identification of risk mitigation strategies?
3. How can community-engaged research be used by EPA to understand cumulative exposures and risks and health disparities, and examine scenario-specific case studies to explore implementation of CRA?
4. How can indicator approaches assist in better understanding the interrelationships between social determinants of health, other nonchemical stressors, chemical agents and the natural

environment—with particular emphasis on place-based contexts and potential for decision-making?

Supporting Tribal Sustainability and Well-being

EPA's [*Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples*](#) (EPA, 2014b) reinforces EPA's commitment to strengthening its engagement with Tribal governments and indigenous communities while fulfilling its trust responsibility to federally recognized Tribes. This policy describes how EPA works with federally recognized Tribes and indigenous peoples throughout the United States, and with others living in Indian country. The Policy integrates 17 EJ and civil rights principles to help EPA protect the environment and public health and address EJ concerns in Indian country. EPA's Tribal Science program is designed to address issues of environmental quality and environmental health in Indian country directly and to provide Tribes with science and tools to implement Tribal environmental programs.

Historical events have adversely changed the environments and traditional food sources specific to many Tribal populations (American Indians and Alaska natives) and have negatively affected Tribal cultural practices and health. For example, environmental degradation and displacement of Tribes from traditional lands have led to the elimination of heritage diets, affecting health, well-being, and social cohesion. Impaired features of Tribal environments are not supporting previously sustainable and healthy diets and lifestyles. These changes, combined with social stressors, might have contributed to the increased incidences of asthma, diabetes, high cholesterol, and obesity in many Tribal communities. Tribal communities also could be more vulnerable and disproportionately impacted by climate change, especially when it disrupts the ability to depend on surrounding ecosystems for food sources, cultural practices, and unique lifestyles. This issue is notable for native Alaskans who face the need to relocate entire communities because of sea level rise and thawing of the tundra. Tribes need evidence-based data and tools to help them identify and anticipate potential environmental problems that could result from changes in their environments and societies.

ORD plays an important role as co-chair of the EPA's Tribal Science Council. This role recognizes ORD's responsibility and ensures that Tribal science priorities are directly considered in ORD research planning and implementation. ORD research to build Tribal sustainability focuses on use of traditional ecological knowledge; development and training in assessment and restoration for proper functioning conditions to restore and maintain Tribal lands and waterways; adaptation by Tribes to climate change impacts; Tribal health issues, including indoor air quality, asthma, and use of indoor cook stoves; collaborative development of decision support; and environmental information access tools. This research is consistent with the principles included in the [*EPA Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples*](#) (EPA, 2014b).

Key science questions:

1. How can traditional ecological knowledge and ecosystem goods and services be used in Tribal-specific assessments and other actions to support Tribal sustainability?

2. What are the key factors in the social, natural, and built environments that result in vulnerability or resilience to stressors associated with environmental toxicants? With climate change?
 - a. How can this understanding contribute to greater Tribal preparedness?
 - b. How do these factors interact with contaminated sites or other community environmental hazards?

Characterizing Climate Justice

Climate change-related cumulative health risks are expected to be disproportionately greater for overburdened communities, in part due to poorer infrastructure that results in lessened resilience to stressors such as flooding or other extreme weather conditions, and in part due to differential proximity and exposures to chemical sources and flood zones. EPA's Climate Adaptation Plan includes focusing on "the most vulnerable people and places." EPA's *Policy Statement on Climate Change Adaptation* states the need to "focus on incorporating consideration of environmental justice into the design and evaluation of adaptation strategies." NEJAC recommendations to EPA in *Conducting Research on Potential Disproportionate Impacts of Climate Change Effects, Mitigation and Adaptation* include conducting research (tools, indicators, maps) to identify the most climate-vulnerable communities to inform climate adaptation and emergency response strategies. Specifically, NEJAC recommended EPA characterize and identify or map communities that are vulnerable to climate change (e.g., based on geographic and demographic vulnerability) and analyze and measure socioeconomic, racial, or ethnic disparities associated with different adaptation and mitigation options.

EPA research will focus on identifying key factors and interrelationships between social determinants of health, other nonchemical stressors, and chemical agents relative to climate change-related impacts for vulnerable populations. EPA has proposed to develop climate vulnerability and community resilience indices as metrics for use in identifying and mapping locations at high risk from stressors such as sea level rise, extreme weather conditions, heat stress, wildfires, changes in precipitation patterns leading to drought and flooding, impacts on communities with contaminated sites and brownfields, and impacts particular to Tribal communities.

Key science questions:

1. What are the key factors in the social, natural, and built environments that result in vulnerability or resilience to stressors associated with climate change?
2. How do these factors interact with contaminated sites or other community environmental hazards?
3. How can this understanding contribute to greater community preparedness?

III. Crosscutting ORD Research

A. Current and Planned ORD Research

This section summarizes ORD’s current and planned research activities as they align with the four EJ science challenge topics. [ORD’s National Research Programs](#) implement these research activities according to their respective StRAPs. Each activity addresses National Research Program-specific outputs and simultaneously contributes to addressing the EJ Roadmap core research areas.

The National Research Program with key responsibility for each activity is provided below in Table 2:

- ACE = Air, Climate, and Energy Research
- CSS = Chemical Safety for Sustainability Research
- HHRA = Human Health Risk Assessment Research
- HSRP = Homeland Security Research Program
- SHC = Sustainable and Health Communities Research
- SSWR = Safe and Sustainable Water Resources Research

Table 2 provides a high-level overview of the distribution of EJ research across ORD’s six National Research Programs. Appendix Table A-1 and Appendix Table A-2 summarize ORD EJ research on a project-by-project basis and provide more detail on EJ research funded through ORD’s Science to Achieve Results (STAR) program.

Table 1. Relative Contribution of ORD’s National Research Programs to ORD’s Environmental Justice Research Challenges

EJ Science Challenge	National Research Program*					
	Air, Climate, and Energy	Chemical Safety for Sustainability	Homeland Security Research Program	Human Health Risk Assessment	Safe and Sustainable Waters	Sustainable and Healthy Communities
Decision Support and Community Engagement	✓ ✓	✓	✓	✓	✓	✓ ✓ ✓
Health Disparities and Cumulative Risk	✓ ✓	✓		✓ ✓ ✓		✓ ✓ ✓
Tribal Science	✓				✓	✓ ✓
Climate Justice	✓ ✓		✓		✓	✓ ✓

* More checkmarks indicate a relatively larger contribution to research in a particular science challenge area.

Developing Decision Support, Citizen Science, and Community Engagement

This research area includes the development of tools to provide access to scientific information by communities and Tribes in a context that increases community engagement in defining, prioritizing, and solving environmental quality, exposure, and health issues. These decision-support tools and resources are expert systems that facilitate access to high-quality science pertinent to the locations and issues of community and Tribal stakeholders outside of EPA as well as our Program partners within EPA. These tools enable users to visualize features of the built and natural environment through publicly accessible GIS tools and to identify potential pollution sources or modeled exposure concentrations and risks for some environmental pollutants. They also provide use cases, tutorials, and step-by-step processes for addressing community-level environmental issues. The tools highlighted here do not comprise the comprehensive list of available tools. Others under development include, for example, decision-support tools to help community stakeholders identify options associated with green infrastructure. A more complete table, the [SHC Usable Tool List](#), provides more examples of tools that can assist communities. SHC also is working on interactive tools to help potential users sort through the many options available, depending on the issues they are addressing.

A. EPA's Cross-Agency Strategies Include "Working to Make a Visible Difference in Communities"

The Action Plan for this strategy includes focused and coordinated Agency action to assist selected communities. Each EPA Region selected a few communities that were "environmentally overburdened, underserved, and economically distressed." EPA's Regions and National Programs coordinate their resources and work to address real community problems and improve lives and conditions. For ORD, MVD is providing scientists with opportunities to work with the Regions and communities on real-world testing and feedback for ORD tools, while the projects provide real benefits to those communities. For example, in Newport News, Virginia, ORD and Region 3 are evaluating the cumulative risk of port-related emissions on the disadvantaged communities nearby, which will help target solutions. In Alexandria/Pineville, Louisiana, ORD is working with Regional staff to evaluate the health implications of creosote plants on nearby neighborhoods and look for sustainable materials solutions. Appendix B describes ORD engagement in 16 of the current MVD projects.

B. The Community-Focused Exposure and Risk Screening Tool (C-FERST) and Tribal-Focused Environmental Risk and Sustainability Tool (T-FERST)

C-FERST and T-FERST are web-based decision-support tools designed to help communities and Tribes, respectively, use their limited resources to identify, prioritize, and manage their environmental public health issues. In Portland, Oregon, and Tacoma, Washington, for example, a beta-test version of C-FERST has been used in conjunction with local community colleges and community groups to increase community engagement in overburdened communities. C-FERST has become the core of a broader effort to leverage other resources and convene partners to identify issues, assess conditions, and address these issues. Communities can map their neighborhoods and add data from EPA databases on the locations of contaminated sites, combined sewer overflows, toxic release inventory sites, and other locations of interest; add

demographic data drawn from the census; and add geocoded data for local community features such as markets providing fresh food. In addition, ORD is working to develop a module within C-FERST to enable its use for expediting the information gathering and organizing HIAs.

T-FERST is being developed with Tribal partners to address Tribal-specific needs for information access, assessment, mapping, and consideration of potential solutions. The United Southern and Eastern Tribes developed a step-by-step roadmap, which includes the use of traditional ecological knowledge that will incorporate approaches to habitat restoration like proper functioning conditions, described in the section, *Supporting Tribal Sustainability and Well-being*. United Southern and Eastern Tribes also are engaging the Alaskan indigenous Tribes for more input to this tool. An open-waters module is under development for T-FERST that will provide historical and current water quality data to assess impaired or improved water quality for water management efforts on the reservation. [SHC Project 2.62]

C. The Community Cumulative Assessment Tool (CCAT)

CCAT is designed to guide community groups through the challenging aspects of CRA in a participatory process with a specific focus on environmental justice. CCAT has a 10-step process for local CRA and prioritization of potential solutions. The tool, based on EPA's *Framework for Cumulative Risk Assessment*, was developed collaboratively with EPA's Program Offices and Regions, and the communities they work with, with critical input from EJ stakeholder groups. The CCAT step-by-step methodology incorporates community-specific and other data into a structured decision-making approach to identify stressors and prioritize solutions. CCAT addresses multiple stressors and susceptibility and vulnerability factors. It combines decision analysis and risk assessment to identify, evaluate, rank, and prioritize stressors and solutions. A beta-test version of CCAT currently is being used in several communities to evaluate its utility in different contexts. In Newark, New Jersey, CCAT is part of a collaboration with Region 2 and a local community corporation to develop and include citizen science measurements in the assessment of multiple stressors and potential solutions and outcomes. In Chicago, Illinois, CCAT is being used in collaboration with Region 5 and the University of Illinois in a partnership to develop best practices and risk reduction related to environmental justice and Superfund considerations. CCAT also is being used in conjunction with C-LINE (Community Line), described below, in near-road and near-port contexts. CCAT will become part of C-FERST to provide decision-support structure in the context of community assessment guidance. [SHC Project 2.62]

D. Health Impact Assessment

HIA is a structured decision process that uses a combination of procedures, methods, and tools to evaluate the potential effect of a proposed project or policy on the health of the population and the distribution of those effects within the population. The World Health Organization identified four core values of HIAs that are consistent with goals of environmental justice:

- Democracy: HIAs are participatory, involving stakeholders, and build collaborations between health and other sectors

- Equity: Reduction of social disparities in health is a central concern in policy-making
- Sustainability: A policy recognizes short-term and long-term health impacts
- Ethical use of evidence: Use is as rigorous as possible, and considers both quantitative and qualitative evidence, drawing on different scientific disciplines

Stakeholder and community engagement is a critical component of HIAs to ensure those affected by the decision have a voice in the process. Research translation, defined as the transfer of knowledge to community members and stakeholders about the relationship between determinants of health and health outcomes, is another overarching goal of the HIA process.

ORD research will produce a free, publicly accessible HIA Resource and Tool Compilation that HIA practitioners at all levels of experience can use to guide them through the HIA process. The Compilation will be designed to provide an extensive list of resources that apply to the HIA process and to the themes present throughout the process, such as equity and community participation; it will provide tools that facilitate data collection and analysis. Additionally, ORD will work with the EPA Regions to increase capacity to assess the impacts of Federal, Regional, State, and local decisions on public health.

ORD/SHC has worked with EPA's Regions and with municipal and community groups on two HIAs that addressed EJ issues, one in Springfield, Massachusetts, and the other in the Proctor Creek neighborhood in Atlanta, Georgia. The neighborhood effort will be expanded to consider establishing an incentive-based approach for increasing green infrastructure within the Proctor Creek Watershed. Proctor Creek is one of the most impaired water bodies in the area. The communities of Proctor Creek experience overlapping concerns including flooding, derelict and abandoned properties, crime, and lack of economic opportunity. The assessment will support identification of the best locations for green infrastructure that maximize public health benefits across environmental, social, and economic determinants of health and where physical properties are best suited for green infrastructure. SSWR is providing extensive analysis of soils in the watershed to contribute to the assessment. Region 4 continues to be a key collaborator. [SHC Project 2.62; SSWR Project 5.02]

SHC will work with EPA's Office of Federal Activities to consider the use of HIA as part of EPA's National Environmental Policy Act/Section 309 reviews to enhance human health considerations in the National Environmental Policy Act process through its ability to

- Provide the lead agencies, stakeholders, and communities with information on the potential health effects of a proposed action and its alternatives, through the broad consideration of impacts on health and health determinants;
- Identify potential disproportionate human health or environmental effects (or both) of a proposed action and its alternatives on people of color, low-income populations, and children and develop recommendations to address those effects; and

- Develop recommendations to improve a proposed action and its alternatives or mitigate against potential negative health impacts before the action is implemented, or both. [SHC Projects 2.62 & 4.61]

E. EnviroAtlas

EnviroAtlas is a collection of interactive tools and resources that enables users to explore the many benefits people receive from nature, often referred to as ecosystem services. Ecosystem services often are overlooked, even though they are critical to maintaining and promoting human well-being. With EnviroAtlas, users can access, view, and analyze diverse information to understand more clearly how various decisions can affect an array of ecological and human health outcomes. EnviroAtlas includes use cases as examples to help new users of the tool. One use case demonstrates the use of the EnviroAtlas for analyzing and planning an urban tree arbor, bringing in spatially explicit demographic information necessary to consider equitable distribution or access to natural amenities. Another use case shows population numbers in an urban near-road environment and the adequacy of vegetative buffers to reduce potential near-source exposures. Such analyses are highlighted as examples for use in planning transportation corridors and placing green spaces and other natural amenities.

EnviroAtlas includes a module, the Eco-Health Browser, that is an easy-to-use interface for a curated database that describes connections between access to natural amenities and health conditions of concern to many communities. For example, users can make links between low birthweight or cardiovascular disease and the provision of ecosystem services—clean air, clean water, recreation and physical activity, and engagement with nature. A user also could start with features of urban ecosystems and learn about their relationships with physical and mental health. Ultimately, this information can be used in decision-making about the siting of roads, the preservation or development of green space, and other environmental issues. The results could be incorporated readily into processes like health impact assessment as supporting data for community objectives. EnviroAtlas is described further in the section, below, on climate justice. [SHC Project 1.62]

F. C-LINE, C-PORT

Transportation (including roadway traffic, airports, and ports) is a critical feature of the Nation's economy. Ports can be considered multimodal transportation facilities as they typically have truck and rail yard facilities for shipping goods to and from the ports. Multiple air pollutant species, such as carbon monoxide (CO), oxides of nitrogen (NO, NO₂, NO_x), particulate matter (PM₁₀, PM_{2.5}), black carbon, and several air toxics can be emitted from these multimodal facilities, affecting communities near the port and along freight-movement corridors.

C-LINE and C-PORT (Community Port) are screening-level models designed to help communities explore the potential improvements to air quality and exposures due to voluntary or mandatory programs. These tools predict concentrations of multiple criteria pollutants (National Ambient Air Quality Standards, or NAAQS) and hazardous air pollutants (key mobile source air toxics) at

fine spatial scales in the near-source environment. Screening-level air quality modeling is a useful tool for examining what-if scenarios of changes in emission volume, such as those due to changes in traffic counts, fleet mix, or speed, or changes in traffic, port, and airport emissions due to equipment or vehicles. EPA's *Guidance on Considering EJ during the Development of Regulatory Actions* (EPA 2015b) encourages the use of screening-level analysis when feasible to recognize opportunities for identifying and addressing potential EJ concerns.

C-LINE was used in a collaboration between ORD and EPA Region 4 to examine the potential impact of port expansion on air quality. As freight volume increases in Region 4 ports, communities near the port and along goods movement corridors could experience increased local-scale air pollution due to increased traffic. C-LINE was used to consider the entire transportation network. In Newport News, Virginia, a community that contains commercial port operations, highways, and multiple industrial facilities, C-LINE was used to compare different roadway pollution scenarios to help identify areas for further research. Draft versions of these tools are currently being applied in selected case studies in conjunction with CCAT and citizen science approaches in the Ironbound District and Port of Newark, New Jersey. The tools will be used in an integrated assessment project on sustainable port communities. [SCH Projects 2.62, 4.61; ACE Projects AIMS-1, PEP-1]

G. Citizen Science

Community engagement in environmental decisions that affect members of the community is enhanced when that community collects its own data, for example, data on air quality, traffic, potential pollution sources such as auto body shops, or locations for access to fresh, healthy food. Collection of data by community members allows communities to participate in the research and development process, to evaluate baseline conditions, and to evaluate changes in environmental conditions after actions are taken to mitigate exposures to environmental pollutants. The C-FERST, T-FERST, and EnviroAtlas tools enable communities to upload local data to maps provided by those tools. For example, Region 10 used C-FERST as a community engagement tool in two communities. For these communities, the presence of Superfund sites was the point of entry for the Region but was not the basis for the use of the tool; C-FERST is helping facilitate interactions between community groups and local community colleges to address the many other environmental health issues in these communities.

The local data remain the property of the communities; none of those data are saved by government computing systems. These decision-support tools are or will be available on the internet free to the public for their use in learning more about issues identified by their communities, mapping sensitive sites or locations of concern, and considering risk management or risk mitigation alternatives. [SHC Projects 1.62 & 2.62]

EPA has developed an [Air Sensor Toolbox for Citizen Scientists](#) and [Community Air Monitoring Training videos](#) to help build community capacity for environmental monitoring. The videos are based on face-to-face Community Air Monitoring Training that provided individuals from

community action groups and Tribes across the Nation an opportunity to consider their own citizen science air monitoring projects in the context of hands-on training and small group discussions with experts in the field of citizen science. ORD and EPA Region 2 piloted community use of air sensor technologies in collaboration with the Ironbound Community Corporation in Newark, New Jersey. These efforts include both the sensor technologies and tools to examine the data collected against the backdrop of community maps. Ironbound and EPA view citizen science projects that connect local residents to air quality data as a way to make public health a priority in communities and to build the capacity for communities to advocate for health-protective policies at the local, State, and Federal levels. ORD research includes developing methods for evaluating low-cost sensors to set performance standards. Setting performance standards for the sensors could allow their use for citizen science applications and enable description of their capabilities and limitations. ORD also has developed technology to help reduce technical barriers to analyzing air quality data with its Real-time Geospatial Data Viewer (RETIGO). RETIGO, together with mobile sensors and potential new sensor technologies, begins to address NACEPT's recommendation to provide robust real-time data that can be applied to fence-line and myriad community applications. RETIGO can serve as a data analysis platform, an interim data processor, or an interoperable module with C-FERST or EnviroAtlas to address community air quality issues.

ORD, together with EPA's Office of Air, is exploring new sensor and information technologies that could form the foundation of future detection of leaks and fugitive emissions, source inventory, and emissions verification strategies. EPA's goal is to develop automated mobile and fixed-place fence-line and in-plant sensor systems to provide continuous information on emissions. Such applications would enhance safe working environments and inform emission inventories for several sectors, including oil and gas production and distribution, landfills and wastewater treatment, agricultural operations, and petrochemical and other industrial facility emissions. [ACE Project EM-1, EM-3]

H. EJSCREEN

ORD notes that EPA developed EJSCREEN as a tool that highlights locations for further review as a starting point for engagement, evaluation, or enforcement efforts. EJSCREEN, C-FERST, and EnviroAtlas all draw from EPA's Geospatial Platform and have some of the same capacities for displaying community-scale information. EPA, State and local agencies, and communities could use these tools together or in sequence. For example, one can identify overburdened or other candidate communities with EJSCREEN, then follow up by using C-FERST, T-FERST, CCAT, and EnviroAtlas or the other tools described above to engage communities by using step-by-step guides for community assessments, gathering more detailed information, and generating and evaluating potential solutions. ORD is working with EJSCREEN developers to link these tools and to update and harmonize the underlying datasets from which the multiple tools draw data.

I. Contaminated Sites and Groundwater

More than 80 percent of the most serious hazardous waste sites in the United States have adversely impacted the quality of nearby groundwater. Groundwater accounts for over 95 percent of the Nation's available freshwater resources, and is the drinking water source for half the people in the United States. Groundwater wells near Superfund sites supply public and private drinking water wells, irrigation and other agricultural demands, and commercial and industrial business needs. No single method exists to characterize communities located near hazardous waste sites, but a recent EPA study found that approximately 49 million people live within 3 miles of Superfund sites or proposed National Priority List sites.

This task will produce applied research products that focus on the temporal and spatial changes in groundwater, vapor intrusion, or contaminated sediments coupled with social and economic factors related to community water supplies addressing Superfund, brownfields, or EJ concerns. One of the most challenging aspects of site remediation is selecting a suitable contaminated site management strategy that incorporates both technical and economical feasibilities of available alternatives that include social variables and site reuse considerations. Research is needed to develop a knowledge base and decision tools to assess and predict temporal and spatial changes in aquifer-based water supplies related to community water supplies. ORD's intention is to focus its efforts on the development of spatially and temporally based models or decision-support tools. [SHC Project 3.61]

Environmental Health Disparities and Cumulative Assessment

ORD research to address environmental health disparities is focused on better understanding the contribution of diverse factors to disproportionate risk, with an emphasis on how nonchemical stressors might modify adverse health effects associated with exposures to chemical contaminants. These factors include the natural, built, and social environments in combination with biological factors and response. ORD focus includes continued updates to toxicity information on a chemical-specific basis to improve the science supporting risk assessments.

A. National Institutes of Health (NIH)-EPA Centers of Excellence on Environmental Health Disparities Research

ORD/SHC STAR research centers are co-funded with National Institute of Environmental Health Science, National Institute of Minority Health and Health Disparities (NIMHD), and National Institute of Children's Health and Human Development (NICHD) to stimulate basic and applied research in understanding environmentally driven health disparities and improving access to healthy environments for vulnerable populations and communities. The centers are designed to foster interdisciplinary research on complex interactions among social, natural, and built environmental systems, conditions, and policies that result in unequal environmental health conditions and disproportionate impacts on (diverse) disadvantaged population groups, communities, neighborhoods, and individuals. Research outcomes are expected to promote innovative strategies to mitigate environmental exposures and health disparities; alleviate system drivers of racial/ethnic and socioeconomic disparities; and improve access to healthy

and sustainable environments for vulnerable populations. Proposals must include community-based research, mentoring, capacity building, and research translation and information dissemination. [SHC Project 2.63 (Appendix Table A-2)]

B. Intramural EPA/ORD Research on Interrelationships among Social Determinants, Nonchemical Stressors, and Chemical Agents

The SHC and ACE programs include intramural EPA/ORD research designed to characterize the interrelationships among social determinants, nonchemical stressors, and chemical agents. The research includes identifying neighborhood and social determinants and land use decisions that influence health outcomes, especially sudden death and respiratory disease. Other research focuses on environmental drivers of public health and well-being specific to communities of color, with a focus on asthma and other critical health outcomes, in the context of stressors that include housing and transportation, socioeconomic status, access to medical care, and exposures to pesticides, toxic metals, mold, and air pollution. Additional asthma research considers novel interventions to reduce asthma disparities. ORD research also considers how chronic stress alters individual response to pollutants.

Of note is that the ACE research program has transitioned its research on NAAQS and multipollutants to new projects focusing on Protecting Environmental Public Health and Well-being (PEP). Although not all PEP projects are focused on environmental justice, they do explicitly address community-scale issues; the potential role of socioeconomic status and other social determinants of vulnerability to the effects of exposure to air pollutants; the identification of modifiable factors in the built, natural, and social environment to reduce exposures, risks, and impacts associated with air pollution; and research translation and outreach. [SHC Projects 2.62 & 2.63; ACE Projects PEP 1, 2, & 4]

C. Cumulative Risk Assessment as an Integrative Approach

EPA has a long-standing interest in CRA. The research described here is intended to advance CRA as an integrative approach for use by EPA Program Offices, Regions, and others, including communities.

A current research emphasis in SHC, HHRA, and ACE is understanding the role of nonchemical stressors and developing analytical methods for CRAs. ORD funded multiple grants through a [2009 Request for Applications](#) (RFA) on this topic and will produce a summary report on this body of research. The research addresses asthma, hypertension, central nervous system function in association with the urban environment, stress, and exposure to air pollutants or metals, and, in one case, in a community near a Superfund site. [SHC Project 2.62]

The HHRA program has proposed research on CRA focused on analytical approaches—for example, grouping stressors to simplify the inclusion of chemical and nonchemical stressors for human health CRA for specific health outcomes. Other examples include integrating nonchemical stressors into the consideration of particulate matter and cardiac function and

integrating ecosystem services into CRA, such as analyzing green space measures and asthma incidence among children. This research is part of HHRA's broad framework for integrating chemical and nonchemical stressors for CRA. Vulnerability information includes the incorporation of vulnerability and cultural factors as shown in Figure 3. [HHRA Project 6]

Figure 3 does not include direct reference to systemic racism and discrimination and their possible contributions to environmental exposure and environmental health disparities, as was included in Wilson's *Ecological Framework for Environmental Justice* (Wilson, 2009) or in Gravlee's discussion of the nested levels of causal inference at multiple scales of human biology with the social and built environment (Gravlee, 2009). ORD anticipates that these factors will be incorporated into some of the research by the EPA/NIEHS Centers for Health Disparities. In addition, the interactions of human biology with the built, natural, and social environments and environmental pollution (the "Total Environment") is the topic of an ORD RFA anticipated to be released in FY17, with social structural factors as a potential stressor to be included in research proposals.

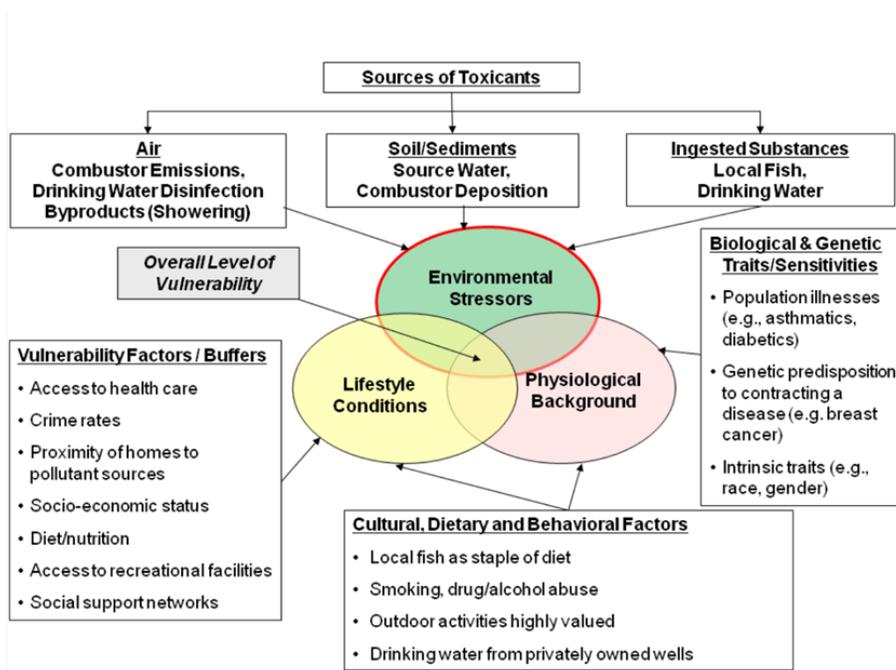
Research into biological susceptibility includes investigating epigenetic mechanisms that might underlie adverse health outcomes associated with combinations of chemical and nonchemical stressors. Epigenetics refers to potentially inherited changes to molecules associated with human genes that change gene expression. These changes might be induced by a variety of conditions, including social stress. Research in the ACE program is aimed at understanding how socioeconomic and various biological factors influence the response of individuals to mixtures of air pollutants. This research is also examining whether living in a disadvantaged neighborhood is reflected in long-term epigenetic changes that, in turn, result in alterations of specific biologic pathways increasing the susceptibility to air pollutants. In August 2015, HHRA conducted a workshop on epigenetics and CRA to explore how epigenetic markers can inform consideration of susceptibility in risk assessment. Proceedings of this workshop will be available this fiscal year. Another task is an integrated effort across the ACE, SHC, and HHRA programs to explore how predictive epigenetic markers might inform neighborhood-based assessment of asthma and cardiovascular diseases in the Research Triangle Park area in North Carolina. [HHRA Project 6; ACE Project PEP-2]

HHRA has also committed to incorporating susceptibility and vulnerability information into assessments in the Integrated Risk Information System (IRIS) and the Integrated Science Assessments (ISA) for NAAQS pollutants and for CRA. [HHRA Projects 2 (IRIS) and 3 (ISA)]

The CSS program conducts research on rapid exposure and toxicity assessment and on development of biological adverse outcome pathways for use in screening of potentially toxic compounds, ultimately to apply to risk assessment. This research is applicable to concerns raised by NEJAC (Table 3) for assessing new products and prioritizing chemicals for IRIS assessments. [SHC Project 2.62; HHRA Project 6; CSS Topics 1 and 2]

In addition, HHRA's Projects 4 and 6 focus on community and site-specific risk. This research area addresses three issues important to overburdened communities: the development of risk assessment values for compounds of concern found at contaminated sites (Provisional Peer-Reviewed Toxicity Values, HHRA-4), site-specific and Superfund regulatory technical support (HHRA-5), and CRA methods and applications (HHRA-6).

Further discussion of cumulative assessment appears in the section on children's environmental health and epigenetics and in the section above on decision-support tools.



Current area of emphasis in human health risk assessment is incorporating ecological endpoints; future work will incorporate HSRP resiliency and SHC wellness indices.

Figure 3. Cumulative risk assessment framework illustrating various potential roles of chemical and nonchemical stressors and buffers.

D. Screening and Developing Provisional Assessments for Previously Untested Contaminants

HHRA and CSS are actively grappling with how to apply emerging technologies to the development of provisional risk assessment values, such as Provisional Peer-Reviewed Toxicity Values for the Superfund program, and for all other assessments, including IRIS. CSS will provide cost-efficient methods and high-throughput data for rapid risk-based evaluation of existing chemicals and emerging materials. CSS, in collaboration with HHRA, is working on a new screening-level assessment product called RapidTox to provide information on data-poor chemicals and to reduce the time, cost, and uncertainty of risk-based chemical management decisions. The goal is to deliver RapidTox assessments for large numbers of data-poor chemicals through an automated computer dashboard and provide a range of information related to hazard, chemical properties, fate and transport, and exposure. The information will include data from traditional sources, when available, and new data streams in development such as

automated read-across methods, high-throughput screening from ToxCast, adverse outcome pathways, high-throughput exposure estimates from ExpoCast, and high-throughput toxicokinetic models. The project will investigate methods to integrate and distill the diverse data streams into quantitative toxicity values with associated estimates of uncertainty to support various decision contexts. The RapidTox assessments will be developed for two case study examples in partnership with EPA Program Offices.

HHRA is exploring the application of these tools and other data-mining approaches, including disease-directed evaluations, to characterize other toxicity endpoints (e.g., liver) and outcomes (e.g., cardiovascular disease, bladder cancer). The HHRA program also is actively exploring how to use adverse outcome pathways to inform mode of action in its assessment products and as a basis for integrating ecological and human toxicity for cumulative risk characterization. [CSS Topic 1; HHRA-6]

E. Children's Environmental Health

Children's environmental health is well described in the Research Roadmap dedicated to that topic. Because more than one in five U.S. children live in poverty, and the poverty rate of black and Hispanic children is roughly twice that of white children (U.S. Census Bureau, 2010), this topic also is critical for the EJ Roadmap. The [Children's Environmental Health and Disease Prevention Centers Program](#) (SHC STAR research co-funded with NIEHS, Appendix Table A-2) addresses children's susceptibility and vulnerability to chemical exposures in the context of the communities in which they live, learn, and play. Community engagement, community outreach, and the incorporation of social determinants of health are major components of this program.

ORD/SHC's intramural research includes experimental studies using rodent models designed to characterize the interactions between selected nonchemical environmental factors of concern in humans (e.g., psychosocial stress, poor diet, maternal obesity) and chemical stressors common to low-income and at-risk communities for induction of adverse outcomes following prenatal exposures. This research will be coordinated with HHRA and ACE research that considers whether social factors might induce epigenetic reprogramming, and whether the epigenome could be useful as a "biosensor" of environmental conditions, broadly defined such as those found in overburdened communities. HHRA is focusing on incorporating genetic and epigenetic susceptibility into CRA.

SHC has also funded extramural (STAR) research on [Healthy Schools: Environmental Factors, Children's Health and Performance, and Sustainable Building Practices](#) to inform school building design, construction, and operation practices on fostering safe and healthy school environments and maximizing student achievement and teacher and staff effectiveness. [SHC Projects 2.62 & 2.63; HHRA Project 6; ACE Projects PEP 1, 2, & 4]

F. Lead Exposure Risk

ORD is working with the Office of Water and Office of Land and Emergency Management (OLEM) to provide better data on lead exposure risk for development of an updated Household Action Level and supporting efforts to revise the Lead and Copper Rule. These analyses are designed to provide data on relative contribution by exposure pathway, geographical differences, and other key factors. [SHC Project 2.63]

Supporting Tribal Sustainability and Well-being

EPA's [*Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples*](#) (EPA, 2014) reinforces EPA's commitment to strengthening its engagement with Tribal governments and indigenous communities and to fulfilling its trust responsibility to federally recognized Tribes. The Policy describes how EPA works with federally recognized Tribes and indigenous peoples throughout the United States, and with others living in Indian country. The Policy integrates 17 EJ and civil rights principles to help EPA protect the environment and public health and address EJ concerns in Indian country. EPA's Tribal Science program is designed to address issues of environmental quality and environmental health in Indian country directly and to provide Tribes with science and tools to implement Tribal environmental programs.

To address Tribal sustainability, Native American institutions have recently increased emphasis on restoring and sustaining traditional, healthy approaches to life that link environmental, economic, and social well-being. Addressing Tribal sustainability requires evaluating environmental conditions and the many factors that contribute to disproportionate exposures and health disparities (e.g., availability of healthy food, restoring the use of traditional foods, differences in exposure factors due to lifestyle and economic pressures). Furthermore, Tribal institutions raise questions about the impacts of stressors associated with climate change on their communities and lifeways (e.g., sea level rise, changing plant hardiness zones, drought, severe weather) and are working with EPA to develop tools, including traditional ecological knowledge, that they can use to anticipate and adapt to these stressors.

A. Tribal Community Grants

The extramural STAR Tribal research program is currently funding six research grants focused on [*sustaining health and environmental quality in Tribal communities*](#) (funded 2014–2017). The research in these grants focuses on Tribal-specific indoor air quality, impacts of climate change on Tribal health, water quality, and access to traditional foods. These community-focused grants include research relevant to children's environmental health and disproportionately affected communities (Appendix Table A-2). These research areas also are priorities of EPA's Tribal Science Council.

The goal of the Tribal community grants is to develop sustainable solutions to environmental problems that affect Tribes by focusing on health impacts of (1) climate change on Tribal populations, and (2) indoor air pollution exposures that derive from or directly affect traditional Tribal lifeways and cultural practices. Specific emphasis is on impacts to vulnerable groups within Tribal communities. Partnering institutions involve Tribal communities through both

university-based and Tribal community-based projects. The Yurok Tribe Environment Program and Northern Arizona University are working with the Alaska Native Tribal Health Consortium to develop a Yurok Climate Change Adaptation Plan for Water and Aquatic Resources. The Swinomish Indian Tribal Community is working with the Skagit System Cooperative and the U.S. Geological Survey's (USGS) Western Fisheries Research Center. Little Big Horn College and Montana State University are working with Crow Tribal members and a Steering committee of Tribal stakeholders. The University of Tulsa, Cherokee Nation Environmental Program, and other Tribal partners are working on home and school indoor air quality interventions. The Alaska Native Tribal Health Consortium (a nonprofit organization) is working on food and water security threats in arctic remote Alaska native villages. The University of Massachusetts is working with Native North American subsistence hunters on air quality in tents.

The current grants extend the efforts and impact of this longstanding program, which has been in effect since 2000. ORD's report, [Decade of Tribal Science](#) (EPA, 2013), summarizes extramural research focusing on cumulative chemical exposures and global climate change that affect Tribes, while integrating cultural, ecological, and human/public health aspects. Past recipients and research summaries are available on the EPA [Tribal Environmental Health Grants Recipient Lists](#) page.

Extramural research on indoor air quality is complemented by ORD/SHC intramural research investigating factors that confer greater environmental public health risk in Tribal areas and communities. These include health impacts of indoor air pollution exposures that derive from or directly affect traditional Tribal lifeways and cultural practices, emphasizing impacts on vulnerable groups within Tribal communities [SHC Project 2.63]. Also included is the development of tools to help plan Tribal housing [SHC RESES projects, Project 4.61]. Active research in the ACE program involves cook stoves, including testing protocols, impacts on indoor air quality and health, life-cycle analysis of fuel alternatives, and impacts on climate [ACE Project SEM-3].

B. Local Environmental Observer (LEO) Network

Alaska's climate is changing rapidly. Local observers can detect changes in weather, landscapes and seascapes, and in-plant and animal communities. The Alaska Native Tribal Health Consortium developed the LEO Network in 2009, recognizing the value of local and traditional knowledge and the need for a tool to document and share environmental observations. The purpose was to increase awareness about vulnerabilities and impacts from climate change and to connect community members with technical experts. LEO uses web-accessible Google Maps to display observations of unusual or unique environmental events that then are shared with LEO members. The maps contain event descriptions, photos, expert consultations, and links to information resources. LEO has grown to include hundreds of participants and is helping increase understanding about the emerging effects of climate change. The LEO Network recently announced the launch of LEO Viewer, a new mobile app for handheld devices. LEO Viewer is a global map and data interface. It allows viewers to experience through text, audio, and images

the observations and technical consults posted by network members. EPA has supported LEO since 2012, through its American Indian Environmental Office's Tribal assistance program and collaborations with Region 10 serving Alaska. ORD has been engaged throughout, exploring citizen science and innovative approaches. LEO applies local and traditional knowledge, science, and modern technology to record and share observations and raise awareness about the conditions in the circumpolar north. This successful collaboration with EPA was highlighted by Alaskan Tribal leaders at the September 30, 2015 White House Citizen Science event.

C. Intramural Research

Five areas of intramural research are important for maintaining and improving Tribal sustainability and addressing Tribal Science Council priorities.

1. *Fish consumption and climate change impacts on Tribal health and well-being.* This research is focused on assessing cumulative Tribal exposures to methyl mercury, PCBs, and other contaminants associated primarily with fish consumption, including cost-benefit analyses to inform Tribal decisions. Research approaches include dietary exposure modeling, meta-analysis of biomonitoring samples including data provided by Tribes, and GIS spatial mapping of Tribal exposures. Ideally, this research will be developed through a collaborative Tribal case study (e.g., Penobscot Indian Nation, Maine) to focus on cumulative exposures and cost-benefit analyses of Tribal decisions intended to restore heritage diets, for example, dietary patterns, dam removals. This research applies population-based exposure models developed to ensure chemical safety at the community/Tribal scale. [SHC Project 2.63]
2. *Proper functioning condition (PFC) of ecosystems.* This research includes ecological assessments and restoration centered on Tribal culture and values and traditional ecological knowledge to help manage ecosystem and human health issues. PFC research is aimed at reducing harmful risk to humans and the environment. Examples include using PFC to (1) reduce risk in the Agency's use of methods for determining total maximum daily loads (Clean Water Act and the new vision for total maximum daily loads); (2) improving water quality, (3) understanding the risk associated with climate change; (4) using leading/lagging indicators of ecosystem integrity, (5) improving best management practices to reduce risk, (6) improving environmental regulations, (7) using big data for PFC assessments and others (EnviroAtlas/T-FERST); and (8) improving methods for human health and environmental risk assessment. This work also includes PFC outreach/capacity building for Tribes including workshops, workshop reports, and GIS and remote sensing to support workshop field sites; Tribal cultural information and traditional ecological knowledge; T-FERST and EnviroAtlas demonstrations; and climate change. Finally, research includes individual PFC assessments, adaptive management and monitoring plans for individual Tribes as requested, natural toxic blooms (identification and sensing), and work with other communities, other Programs, Regions, State and local communities, and the International Commission for Environmental Cooperation. [SHC Project 2.63]

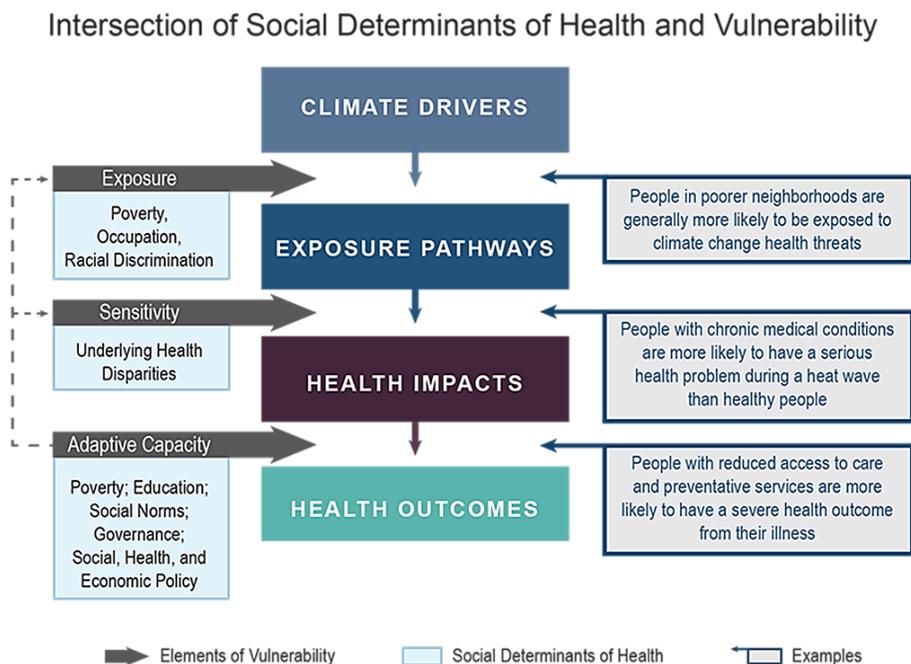
3. *Harmful algal blooms: Research for forecasting and early detection of harmful algal blooms in Tribal areas.* Tools will be developed to characterize known toxins and identify and characterize unknown toxins produced from natural toxin outbreaks [i.e., *Prymnesium* (golden algae), *Microcystis*, *Anabaena*, *Cylindrospermopsis*, *Euglena*, and other, as yet unidentified, algal toxins]. Preliminary studies focus on identifying key *Prymnesium* toxins produced in inland ponds and lakes that are on Tribal lands. Temporal, short- and long-term trends of the physicochemical relationships of pH, temperature, total nitrogen, total phosphorous, calcium, and magnesium (and potentially other chemical parameters) —and the toxins produced—will be analyzed, potentially to develop predictive forecasting tools (real-time chemical sensors) for natural toxic blooms. This research includes potential health impacts of interactions between naturally occurring arsenic in groundwater and algal toxins. [SHC Project 2.63; SSWR Project 4.01]
4. *Tribal childcare center research.* This proposed research would examine how time is spent at Tribal childcare centers and how that might affect young children’s exposures to various chemical and biological agents. This research, a collaboration among EPA Region 10, the Indian Health Service, and ORD, will provide data on the environmental concentrations of lead, allergens, pesticides, PCBs, and other chemical and biological agents in Portland Area Indian country childcare facilities. Valuable information also is expected on nonchemical stressors that young children who attend daycare might experience. [SHC Project 2.63]
5. *Development of a Tribal Well-Being Index.* This index integrates environmental, social/health, and economic domains to provide a metric for holistic well-being in the Tribal context. Such an index is useful for evaluating the potential impact of Tribal decisions that affect ecosystem, social, and economic services on important contributors to well-being like social cohesion, education, and cultural continuity. The Tribal Well-Being Index is an index constructed from indicators from the environmental, social/health, and economic domains. It differs from T-FERST in that T-FERST is a broad information delivery and mapping tool tailored for Tribal use. [SHC Project 2.64]

Characterizing Climate Justice

Climate change threatens human health and the environment, but its impacts do not affect communities equally. Emerging research has linked vulnerability to climate change and capacity to adapt to its impacts to community socioeconomic and demographic characteristics (e.g., race, ethnicity, income), access to social health and environmental services, level of education, and level of preparedness (Figure 4). The following highlighted research activities address the importance of building community resiliency to plan for, adapt to, and recover from the unmitigated effects of stressors associated with climate change.

ORD is developing tools to help community decision-makers and planners assess their vulnerability to the impacts of climate change, and better understand how all communities with emphasis on EJ communities might benefit from using these tools (Figure 5). ORD is actively engaged with the National Science Council, Office of Science and Technology Policy, Council on Environmental Quality, Federal

Emergency Management Agency, and Centers for Disease Control and Prevention to develop improved information about community-level vulnerabilities. ORD also is actively working at the interagency level to expand access to information on projected climate impacts more generally. These interactions enable EPA and ORD to ensure that EJ issues are incorporated into broader, cross-agency activities and programs.



The boxes on the left provide examples of social determinants of health associated with different elements of vulnerability. The boxes on the right illustrate examples of the implications of social determinants on increased exposure, increased sensitivity, and reduced adaptive capacity. Adaptive capacity can affect exposure and sensitivity and the resilience of individuals or populations experiencing health impacts by influencing access to care and preventive services (USGCRP, 2016, Chapter 9).

Figure 4. Increased exposure, increased sensitivity, and reduced adaptive capacity affect vulnerability at different points in the causal chain from climate drivers to health outcomes.

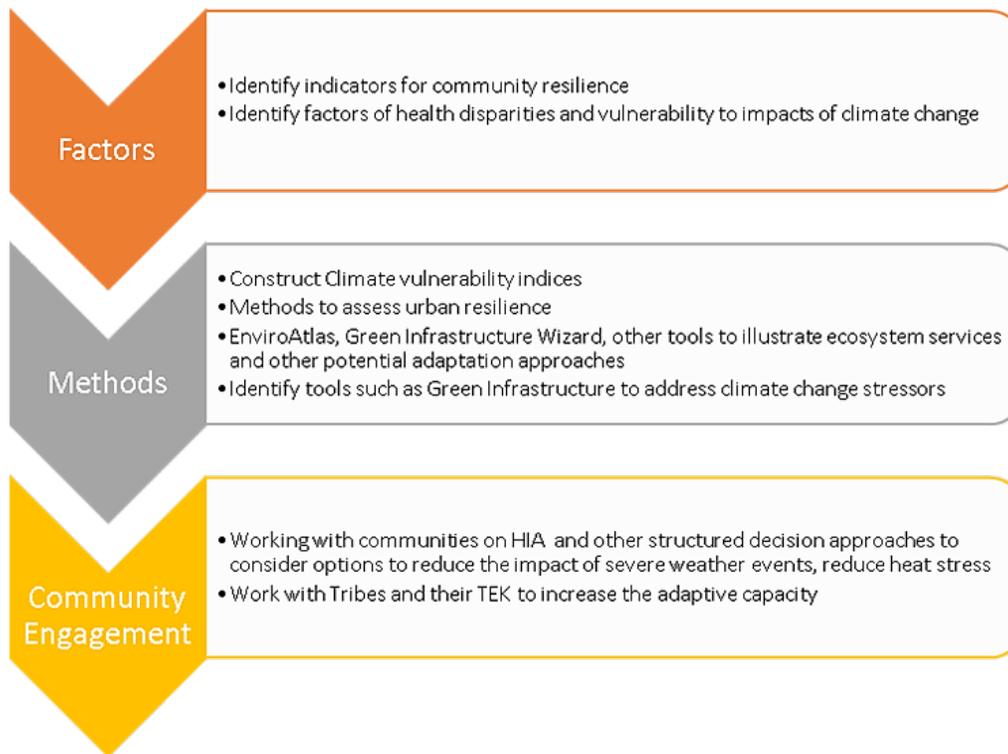


Figure 5. Integration of research on global climate change and community resiliency.

ORD research to develop resilience in vulnerability to climate change includes:

A. Climate Resilience Screening Index and Community Environmental Resilience Index

Climate resilience focuses on enhancing the performance of a system’s capacity to adapt (built or natural) in the face of multiple hazards (e.g., sea level rise, increased variability of seasonal temperatures, increased incidence of storm events and flooding), rather than preventing or mitigating the losses associated only with specific events. SHC has proposed a feasibility assessment for building a Climate Resilience Screening Index (CRSI)—a composite measure of community functions as they relate to community sustainability. This effort proposes to build on the development of indicators for urban climate change resilience developed in the ACE program and indicators and metrics used in existing community and climate resilience evaluations [e.g., [Rockefeller Foundation-ARUP City Resilience Framework](#), [European Commission Index for Climate Resilient Development](#)]. CRSI will describe a community’s (e.g., Region, State, county, city, town, neighborhood) capacity to recover societal and economic functionality, so that people living and working in these spatial units—particularly the most vulnerable—survive and thrive after encountering climate exposures. [SHC Project 2.64]

The Community Environmental Resilience Index (CERI) is a tool under development by HSRP that would allow communities to consider EJ populations in their emergency preparedness activities. Specifically, CERI enables communities to assess their resilience to environmental disasters and to make or advocate for decisions that improve their resilience. This set of indicators relates to

environmental services, such as clean water, and builds on the National Institute of Standards and Technology's general community resilience planning guide focused on the built environment and infrastructure.

As for CRSI, this research combines environmental and social science research. CERI is not focused specifically on stressors associated with climate change, but, rather, on improving community resilience to disasters that can affect human health and disrupt water, waste, and energy systems. CERI is part of a broader HSRP effort to develop tools and methods for effective preparedness and response, including environmental resilience assessment tools to minimize environmental risks associated with disasters, to return critical environmental and ecological services to functionality quickly after a disaster, and to reduce vulnerabilities and risks to future incidents. CERI will be producing a preliminary assessment of EPA community-based resilience tools. The SHC program has a longer-term effort focused on developing a synthesis report on quantitative and qualitative indicators of resilience in human and natural systems. [HSRP Topic: Remediating Wide Areas; SHC Project 2.64]

EPA actions to support emergency preparedness in communities take place in EPA's Program Offices. This support highlights the importance of community or Tribal engagement and attention to vulnerable community members. See, for example, this EPA Connect blog entry on [Local Preparedness](#) (EPA, 2015e) and this EPA fact sheet, [Enhancing Local Planning under the Emergency Planning and Community Right-to-Know Act](#) (EPA, 2015f).

The ACE program includes several efforts directed toward developing community resilience indicators. These efforts include the development of methods to assess urban resilience as a path toward sustainability under climate and land use changes. One method will assess the capability of different types of communities to withstand the impacts of average and extreme climate changes without breakdowns in their economies, natural resources bases, or social systems (resilience). This project is designed to evaluate whether (1) differences in urban ecosystem resilience can be identified using common sets of metrics or composite metrics and (2) typologies of urban ecosystems can be developed based on characteristics of urban areas and other factors to extrapolate information to other urban ecosystems. The urban resilience project is designed to provide outputs that can inform and help prioritize policies and measures that foster greater resilience. [ACE Project CIVA-3]

B. EnviroAtlas

Additions will be made to existing tools that illustrate the links between ecosystem services and potential mitigation of climate change impacts such as heat stress, extreme weather events, water quality and quantity; incorporation of climate scenario time series viewer into EnviroAtlas to allow users to consider potential changes over time in temperature, precipitation, water supply and demand, sea level rise. [SHC Project 1.62]

C. Wildfires

ACE research on the actual and perceived impact of a wildfire on a local community in terms of social, economic, and environmental consequences shows that forecast-based interventions can reduce the health and economic burden of wildfires. This is critical for environmental justice because this research also showed that health impacts were significantly worse in a community with lower socioeconomic status. [ACE Project PEP-1, 2, and 4]

D. Climate Change Impacts in Communities with Contaminated Sites

Proposed research includes identifying key factors and interrelationships between social determinants of health, other nonchemical stressors, and chemical agents with respect to climate change-related impacts for vulnerable populations residing near water/wastewater treatment facilities or contaminated sites. This research will assemble a broad range of community vulnerability indicators to conduct GIS-based statistical analyses to examine (1) the U.S. communities most vulnerable to potential flooding of water/wastewater treatment facilities or contaminated sites; and (2) disparities associated with the most vulnerable communities and particular groups based on socioeconomic, racial and ethnic factors, and proximity to water/wastewater treatment facilities or contaminated sites vulnerable to flooding. [SHC Project 2.63]

E. Research on Technology for Small Water Systems

This grant-funded research focuses particularly on those small systems in areas susceptible to extreme weather events including drought (Appendix Table A-2). These grants are designed to increase community resilience to threats to their drinking water supplies. The grant to a consortium of colleges led by Lincoln University, a historically black college and university, focuses on the development and implementation of surface water treatments. A second grant is focused on point-of-use water treatment systems in the Paso del Norte Region. This research aims to develop small drinking water treatment systems through community participatory research in the 12 *colonias* in the Paso del Norte Region, which includes El Paso, Texas, and Otero and Dona Anna counties of New Mexico. [SSWR Project 6.03]

1. See section on Tribal sustainability and well-being for additional research addressing potential impacts and adaptation to climate change.
2. For additional discussions and details on specific research gaps and priorities, see the *Climate Change Research Roadmap*.

IV. Research Gaps and Priority Research Needs

The EJ Research Roadmap presents a broad inventory of ongoing ORD research and development addressing different facets of environmental justice. Critical research that is not yet fully part of EPA's research effort are described here as research gaps. These have been identified by EPA's advisory groups, EPA scientists, and through review of the scientific literature.

Environmental health disparities, cumulative assessment, and the built, natural, and social environments. NEJAC (NEJAC, 2014), Healthy People 2020 (DHHS, 2010), and CHPAC (2013) share a common call for understanding the driving factors that lead to health disparities and the relative magnitude and contribution of those stressors. Although EPA research has begun to address issues in CRA including the integration of chemical and nonchemical stressors, a gap remains in integrating the holistic determinants of environmental health and well-being and developing tools and analytic methods to apply this knowledge to generation of policies and solutions to support communities. These factors include economic stability, education, social and community context, health and healthcare, and the neighborhood and built environment (DHHS, 2016). In other words, research to inform cumulative risk and cumulative impact assessment should address the total environment consisting of chemical and nonchemical stressors in interaction with the natural, built, and social environments where people grow, live, work, and age. This research should answer questions such as:

- How do the cumulative effects of exposures to multiple environmental chemical contaminants combine with the effects of stressors in the built, natural, and social environments to affect health?
- How are potentially overburdened communities exposed differentially to environmental hazards and contaminants, and what are the drivers for such exposure scenarios? How does differential exposure information increase our understanding of environmental contributions to disproportionate impacts on health?
- Can “big data” approaches, for example, the public health exposome (Juarez, et al., 2014), be used to address the complex relationships among the environment, personal health, and population disparities? What steps are needed to populate and maintain a public health exposome database?
- What approaches can be used to overcome issues in access to health data to be able to connect exposures from the built, natural, social, and chemical environments to critical health outcomes? Will projects like the [CDC/RWJ 500 Cities Project](#) or the [NCVHS effort on using sub-county data](#) provide usable data?
- How can an understanding of the relative contribution of different stressors be used to inform cumulative impact assessment methods such as health impact assessment to promote decisions that address multiple environmental drivers of health disparities?
- What part do factors such as age, gender, and urban vs. rural play in environmental health disparities? How do empowerment issues intersect with demographics and other spatial aspects of exposure?

Equitable distribution of ecosystem services. This gap expands on a subset of the cumulative assessment and impact research addressing quality and accessibility to natural amenities. As communities look to provision of services in the built and natural environments to address health and community well-being issues (e.g., Dustin, et al., 2009), whether these services are equitably distributed must be questioned. Recent literature has expanded the focus of environmental justice beyond

disparate exposures to environmental toxicants to potential uneven, unjust, or inequitable distribution of ecosystem services and the health benefits they provide (Boone, et al., 2009; Jennings, et al., 2016; Jennings, et al., 2012; Jennings and Gaither, 2015; Landry and Chakraborty, 2009). Sacoby Wilson, in his ecologic framework to address justice and health issues (Wilson, 2009), describes both salutogenic (health promoting) and pathogenic features of the environment. Jennings, et al. (2016) expand on this concept for the natural environment in their review of connections between social determinants of health as defined by Health People 2020 (economic stability, education, social and community context, health and healthcare, and the neighborhood and built environment) and benefits linked to ecosystem services provided by urban green spaces. An understanding of the linkage between ecosystem services and the broad domains of human well-being—including factors beyond health, such as education, social cohesion, spiritual and cultural fulfillment, safety and security, living standards, and connection to nature (Smith, et al., 2013)—has been built into a Human Well-Being Index (Summers, et al., 2014). EPA’s EnviroAtlas is a tool that can facilitate analysis of who in a community is benefiting from urban green spaces, arbors, and other features of the natural environment.

Gaps remain, however, in several areas. For example, how are ecosystem services distributed and who are the beneficiaries, especially in urban ecosystems? EPA’s Final Ecosystem Services Classification System (Landers, et al, 2016) makes clear that both the definition and valuation of ecosystem services depend on the environmental class and biophysical supply of a particular natural amenity and who it benefits. The challenge for identifying beneficiaries is that they could differ based on social drivers and social perspective. Ernston (2013) draws clear attention to social and political factors that affect definition and valuation of ecosystem services. These factors might contribute to inconsistent findings on disparities in distribution, access, and quality of urban ecosystem services, such as parks and green spaces (Smiley, et al., 2016; Bruton and Floyd, 2014; Floyd, et al., 2008). Several science questions are outstanding⁴:

- How are parks and other green spaces distributed and utilized across different communities (Boone, et al., 2009)?
- What criteria for social justice would be appropriate for ecosystem services valuation (Shi, et al., 2016)?
 - How are ecosystem services perceived and valued among different populations at community scale?
 - How are ecosystem services assessed in overburdened communities, especially those related to social interactions, physical activity, and climate adaptation (Jennings and Gaither, 2015)?
- To what extent can urban green spaces and other ecosystem services mitigate existing health disparities; what is the strength of their influence relative to other neighborhood factors; and what are the interactions between ecosystem services and those other factors?

⁴ A number of these are adapted from Jennings, Larson, and Yun, 2016.

- How is the distribution of green infrastructure linked to environmental drivers of health such as air quality, water quality, and heat stress in overburdened communities?
- What are the associated ecosystem, societal, and economic benefits of improved environmental management? Do these accrue in the community?
- What pathways between humans and interactions with nature lead to positive health outcomes?
 - What factors influence communities' awareness and appreciation of ecosystem services and use of that information in setting priorities?
- How do different land uses and land use decision-making processes contribute to environmental health disparities? What approaches could communities take to reduce or prevent impacts from land use that lead to environmental health disparities?

Standardized methods and metrics for EJ analyses. Mohai and Saha (2007, 2015a) showed that different proximity metrics used in spatial analysis can give very different magnitudes of effects when analyzing for associations between demographics and siting of locally unwanted land uses, such as hazardous waste treatment, storage, and disposal facilities. In particular, actual distance-based metrics are essential for characterizing disparate siting and exposure risk (Mohai and Saha, 2007; Bullard, et al., 2008). These distance-based metrics contrast with metrics (unit-hazard coincidence methods) that use demographics of a geographic unit (e.g., county) in which a hazard exists as a surrogate for distance. They also showed that longitudinal analysis of the development of disparities in siting of locally unwanted land uses is essential in developing appropriate policy responses to ameliorate existing disparities and preventing the development of new sites (Mohai and Saha, 2015a, 2015b). EPA's EJSCREEN has adopted distance metrics, where possible. EPA researchers need to be aware of the costs and benefits of different methods of analysis (Sheppard et al., 1999).

Research gaps include longitudinal data sets that can be used for further analysis of siting disparities and national-level evaluation of racial and socioeconomic disparities for additional environmental hazards, including leaking underground storage tanks and combined sewer overflows. For many hazards, local evaluations are available (e.g., Wilson 2013), but national analysis is difficult because of lack of national-scale data. For example, EPA has developed a method for estimating private drinking water well density. If this method can be used to map drinking water wells, in conjunction with the mapping of potentially leaking underground storage tanks, an EJ analysis could be done to evaluate this risk to overburdened communities.

Many spatial analyses, whether using distance-based metrics or unit-hazard coincidence methods, use proximity as a surrogate for exposure risk. These analyses would benefit from the use of actual air, water, and land quality and exposure estimates. For example, Mohai and Saha (2015b) recommend the use of regression models of land use to construct historical air quality estimates in particular locations based on satellite imagery. Other tools under development such as the SHC program's C-Line and C-Port provide local-scale estimates of air quality and exposure risk based on historical meteorological data and

emissions inventories. Downscaling of air quality estimates from the Community Multi-scale Air Quality (CMAQ) system also might be used to evaluate local-scale historical air quality estimates.

Looking forward, analyses based on estimates of exposure risk that are more sophisticated might be used in building methods for assessing cumulative pollution burdens for use in facility permitting and generation of safety buffer standards between residential populations and industrial facilities (Bullard, et al., 2008).

Social science capacity. Environmental exposures need to be considered in the context of the community or social environment in which people actually live (Olden, et al., 2015). Understanding this context is the role of social science. ORD's lack of social science capacity is a critical gap that cuts across all research needed to address EJ issues. EPA needs social scientists to provide the appropriate socioenvironmental factors to be included in all phases of research, including problem formulation, experimental design, and research implementation in understanding exposure and health disparities, usage and valuation of ecosystem services, and continued research on disparate siting practices. For the purposes of evaluating environmental justice, anthropology, sociology, social psychology, and economics are important fields to add to ORD's skill mix.

For example, in epidemiological and other biomedical research, race is often used as a surrogate for an unspecified combination of environmental, behavioral, and genetic factors (Lin and Kelsey, 2000; Gravlee, 2009). Biomedical anthropology, however, asks questions and provides study designs that disentangle notions of genetic determinism and race and provide evidence on the effects of systemic racism in producing biological inequalities (Dressler, et al., 2005; Non and Gravlee, 2015). A typical biomedical approach to examining the differences in prevalence of hypertension among black and white Americans might search for associations between DNA-based estimates of African genetic ancestry and hypertensive phenotypes. In one study of hypertension, researchers investigated the association between culturally ascribed skin color categories versus skin pigmentation and hypertension, and found that skin color status in a color-conscious society predicted hypertension significantly better than genetics (Dressler, et al., 2005; Non and Gravlee, 2015). Another study found that education, but not genetic ancestry was associated with blood pressure among African-Americans in the United States (Non, et al., 2012). Searching for biological pathways underlying these environmentally and societal-based differences, for example, social and behavioral epigenetic studies, will require social science expertise (Mulligan, 2012).

The need for social science also applies to ecosystem services beyond the need for economists to understand and incorporate ecosystem service valuation into decisions. As discussed above, a social science perspective helps show that social practice moderates the generation of ecosystem services through urban development patterns and day-to-day maintenance of urban ecosystems and who benefits from these (Ernstson, 2013). For example, from a global or regional biodiversity perspective, given a finite number of trees to be planted, placing new trees where larger tree islands already exist to increase landscape connectivity of trees would be a better option (Ernstson, 2013; Heynen, 2003). From the perspective of local justice and the equitable quality of life through equal interaction with urban

trees, however, planting trees where there are none is better (Landry and Chakraborty, 2009; Holtan, et al., 2014). This means that ecosystem services are not simply “out there,” even when one includes the beneficiaries, but, rather, that they are entangled with social and political processes (Ernstson, 2013). Social science is needed to move between these scales of broadly viewed biophysical benefits and place-based microenvironmental benefits (Ernstson, 2013; Heynen, 2003).

Social science input is also critical with respect to culturally important landscapes or resources in the context of climate change. ORD’s *Climate Change Research Roadmap* raises this point in the context of valuation—putting a value on things like changes in snow cover, or heritage sites and historical sites with cultural value that might be subject to inundation from sea level rise, is very difficult. This point might be most important in a Tribal context, but important colonial historical sites that are vulnerable to sea level rise, or landscapes (e.g., Glacier National Park) that have broader cultural value more broadly, also might exist. How to include those in an evaluation of loss due to climate change is not clear. Equity in protection and preservation of historic sites of importance to Tribes and people of color, however, is a critical element of *recognitional justice*—the need for recognizing and respecting communities that suffer from environmental and other injustice (Schlosberg, 2004; Cook and Swyngedouw, 2012).

In addition, few studies have addressed issues of social vulnerability as part of local climate change adaptation or have evaluated how emerging adaptation plans affect overburdened communities and populations (Shi, et al., 2016). Planning at the municipal level raises a host of issues: the possibility that poorer and less capable cities will be unable to implement adaptation planning; limited input into adaptation planning decisions by a broad range of municipal departments and by social or EJ groups; the probability that privately funded adaptation strategies will protect wealthier areas and exclude poorer areas (Anguelovski, et al., 2016); and that local adaptation interventions can exacerbate negative effects elsewhere, for example, embankment in one area can exacerbate flooding elsewhere (Shi, et al., 2016). As in the discussion of ecosystem services (above), the question becomes one of climate adaptation for whom, by whom, and how (Anguelovski, 2016). Addressing these issues requires social science research to address the following [see additional questions in Shi, et al. (2016)]:

- To what extent do climate adaptation plans developed by environmental and land use planning departments prioritize addressing social vulnerability?
 - How has participation of a broader set of municipal departments and community groups early in adaptation planning affected strategies and outcomes, especially for socially vulnerable groups?
- To what extent are urban and infrastructural design decisions for climate adaptation creating new waves of displacement or other forms of maladaptation?
 - Under what conditions do infrastructure projects for climate adaptation prioritize or complement efforts to address the needs of overburdened communities?
- What tools (such as big data, open data, crowd sourcing) and planning scales (such as communities, Regions, States) enable a broader range of municipalities to take steps to adapt to climate impacts?

Broader recommendations: EPA’s National Environmental Justice Advisory Council has produced an extensive set of [recommendations for integrating environmental justice in the EPA’s research enterprise](#) (NEJAC, 2014). These recommendations are summarized in Table 3. The comprehensive reach of this NEJAC table makes it a helpful summary of the breadth of recommendations received by ORD from several advisory groups. The Science Advisory Board (SAB) and Board of Scientific Counselors (BOSC), for example, emphasized the need for community input. NACEPT provides more detail, emphasizing the development of monitoring and assessment technologies along with technologies to better communicate real-time information about ambient pollution levels and for emergency response.

The scope of this Roadmap is not adequate to address all of these issues, but ORD and the Agency have activities that are addressing many of them (bolded text in Table 3), although the level of effort varies. For example, this Roadmap lists a considerable body of research focused on the needs of American Indians (Table 3, Item 1-1); this research, however, does not address the needs of all indigenous peoples. For issues like the need to partner to advance access to healthcare in communities experiencing environmental inequities (Table 3, Item 1-17), ORD has initiated programs like [Healthy Heart](#) to deliver critical environmental health information to practitioners in communities such as North Carolina’s “Stroke Belt,” developed research on the efficacy of preventive measures in wildfires areas referenced above in the section on climate justice, and funds research that informs research translation actions by Pediatric Environmental Health Specialty Units. ORD does not, however, play a direct role in providing healthcare, and is more deeply engaged in the development and application of HIAs (Table 3, Item 1-14). ORD’s work to increase the rigor and use of science in HIAs has been noted by the National Prevention Council, which identifies EPA as the Federal government leader in this area, and groups such as the National Association of City and County Health Organizations are using ORD’s report on HIAs as instructional material (personal communication). ORD’s initial HIAs were done in partnership with EPA’s Regions and local government and community groups from overburdened communities.

The nonbolded headings in Table 3 highlight some of the existing gaps in ORD’s portfolio. These gaps occur primarily in the areas of community engagement in setting the research agenda and assessing outcomes.

Community engagement (Table 3, Item 2-1): ORD has made great strides in performing or funding community-engaged research, but not necessarily in engaging communities per se in setting this research agenda. This need was emphasized by the EPA SAB-BOSC Executive Council: Incorporate input from communities to identify problems associated with environmental, biological, behavioral, social, economic, and spatial stressors and how they interrelate.

In the area of community-engaged research, ORD includes provisions requiring or strongly recommending community engagement in funding to STAR Centers for Children’s Environmental Health and Minority and Health Disparities, and the newly funded ACE Centers.

ORD’s SHC research program has directed its researchers to conduct actionable research on problems formulated at the stakeholder level, and to conduct its research through participative and collaborative case studies to build on stakeholder expertise and to focus research and development on the end user.

SHC has expanded its funding for research proposed by EPA's Regions for community-scale projects through its Regional Sustainable Environmental Science (RESES) program; many of these projects address community engagement and environmental health in overburdened Tribes or communities near ports, roadways, or contaminated sites or that are considering green infrastructure approaches to myriad problems rooted in stormwater or wastewater handling. All of ORD's National Research Programs collaborate with EPA's Regions in Regional Applied Research Efforts, many of which address issues in overburdened communities. Further, the citizen science research and outreach led by ACE has engaged communities.

These efforts, however, while engaging communities, are not necessarily working with communities to set the research agenda—in most cases, a university partner or EPA Region acts as a surrogate for the community in proposing the research. ORD's SHC did sponsor listening sessions during the early development of its program, but these focused on broad areas of interest to planning at community governance levels.

EPA's STAR program has demonstrated the benefits of truly engaged community-based participatory research, with community partners driving research in areas like health and safety for families of pesticide applicators. Recently ORD researchers have begun to engage with community members at the biannual Community Involvement Training Conferences and have found these to be extremely helpful in orienting them toward the development of their technological or science products. The July 2015 Community Involvement Training Conference was sponsored by EPA's Office of Air and Radiation, Region 4, the Office of Environmental Justice, and OLEM. ORD should work with EPA's programs, Regions, Office of Sustainable Communities, and with community stakeholder groups to expand opportunities for direct interaction of its scientists with community members. These could be at listening sessions, perhaps sponsored jointly by ORD and EPA's Regions, which are incorporated into ORD's regular planning cycle. Direct interaction also could occur at events such as the July 2015 workshop ACE sponsored to build capacity for citizen science where ORD scientists can learn more about community needs for measurement or other technology. These events are important because they could provide opportunities for community members to engage directly in the development of the science and technology through their experience with the usability and applicability of the tools.

Assessing outcomes (Table 3, Items 3-1, 4-1, 4-2): Assessing direct outcomes resulting from ORD research is often challenging because, while ORD provides science and technology, EPA's programs are largely implemented through its Program and Regional Offices or through delegated parties at the State level. Even so, the importance of monitoring or assessing outcomes of decisions made that affect community well-being is at the heart of much of the research in ORD's National Research Programs. For example, the SHC StRAP emphasizes the development of structured decision-making approaches like HIAs that include a cycle of monitoring or assessment of outcomes to drive further improvement of conditions or adaptive management. The HSRP similarly employs a structured cycle including "Lessons Learned" to reduce vulnerabilities and increase resilience to contamination events or natural disasters.

SHC has also invested resources in developing indicators and indices, such as the Human Well Being Index (Summers, et al., 2014) and the Environmental Quality Index (Messer, et al., 2014), as metrics of both baseline conditions and to evaluate changes effected by voluntary or regulatory practices. The Environmental Quality Index contains a comprehensive set of indicators, covering many of the recommendations for candidate indicators/measures made by Payne-Sturges and Gee (2010). Although the Environmental Quality Index does include a social domain incorporating available census variables on housing, education, income, crime, and discriminatory lending practices, it does not include broad social processes such as residential segregation, community stressors in addition to crime, neighborhood resources, or structural factors such as governance structure or the taxation system (Payne-Sturges and Gee, 2010).

ORD offers its science and tools needs to its partners in programs such as OLEM's brownfields program, the Great Lakes National Program Office, EPA's Regions, and the Agency for Toxic Substances and Disease Registry for planning remediation or restoration activities. ORD needs to engage these partners further to evaluate the longer-term outcomes of community-scale actions in terms of progress toward restoration of the environment and broad community revitalization—the real steps toward sustainability. Continued support for citizen science will be critical to these efforts; especially important will be to develop clear standards and use of citizen science data by communities in communicating with the Agency. These standards should be developed through collaborations with ORD, EPA Program Offices, technology developers, and community stakeholders.

Promoting training of the next generation (Table 3, Items 2-5, 2-6): EPA Administrator Gina McCarthy hailed the success of the ORD–Region 2 citizen science project in Newark saying, “Community-based air monitoring projects like this one make public health a priority and pay multiple dividends. We not only gain valuable information, we also help community members gain the skills and experience they need to conduct citizen science projects in their communities to better protect their families.” ORD has long played a role in funding fellowships at the university and post-graduate levels to advance STEM (Science, Technology, Engineering, Mathematics education) capacity, with an emphasis on underserved communities and the economic opportunities that higher education brings. The Office needs to move beyond that to build an infrastructure and partnerships to increase the capacity of community members to engage meaningfully in the policy and planning decisions that affect their communities. ORD, working with Regional partners, has taken small steps. For example, local community colleges developed a curriculum based on C-FERST in Portland, Oregon, and Tacoma, Washington, and engaged in citizen science to map features of their communities (Stewart, et al., 2016). Further development of academic-community partnerships to build capacity, along with the development of educational curricula that can incorporate sophisticated GIS and other scientific information delivery and visualization tools into secondary education, have the potential to promote direct engagement of the community in the decisions that affect their lives.

Table 3. Summary of the NEJAC (2014) Recommendations

Bold lettering indicates some level of ORD activities in those areas (adapted from NEJAC, 2014).

TOPIC AREA	Opportunities to address environmental inequities	Community inclusive processes	Tailoring ORD tools for community use	Assessing impact of ORD research	Skills needed to address EJ
RESEARCH NEEDS, GAPS AND FRAMEWORK	<p>1-1. Incorporate Research Needs of American Indians, Alaskan Natives, Native Hawaiians and Other Indigenous Peoples</p> <p>1-2. Advance Research on Health Disparities</p> <p>1-3. Conduct and Collect Data for Longitudinal Studies</p> <p>1-4. Support Biomonitoring Research</p> <p>1-5. Conduct Research and Collaborate to Identify and Address Air Quality "Hot Spots"</p> <p>1-6. Conduct Research to Support Diesel Exhaust Regulations</p> <p>1-7. Conduct Research on Potential Disproportionate Impacts of Climate Change Effects, Mitigation and Adaptation</p> <p>1-8. Revise the EPA's Definition of Sustainability</p> <p>1-9. Conduct Research on Incentivizing Business Performance Beyond Compliance</p> <p>1-10. Amplify Uncertainty Analyses to Inform Risk Assessment, the Application of the Precautionary Principle and Decision Making</p> <p>1-11. Assess New Products</p>		3-1. Collect Data for Evaluating Improvements in Environmental Conditions and Health Outcomes		
	<p>1-12. Prioritize Chemicals in IRIS Process</p> <p>1-13. Investigate Potential Disproportionate Effects of Pesticide Exposure of Rural and Urban Farmworkers</p>	2-1. Engage Communities in Setting the Research Agenda	<p>3-2. Encourage Collaboration in Setting the Research Agenda</p> <p>3-3. Identify and Engage Relevant Stakeholders</p> <p>3-4. Engage Stakeholders in the Development of Research Products and Tools</p>		
RESEARCH AGENDA DEVELOPMENT IN COLLABORATION WITH STAKEHOLDERS	1-14. Promote Health Impact Assessment Method	2-2. Incorporate Community-Engaged Research Models into Research Program Implementation	3-5. Develop Personnel Exchanges	5-1. Increase Social Scientists on EPA Staff and as Consultants	5-2. Enhance Training of ORD Scientists
	1-15. Adjust Extramural Research Review Process				
RESEARCH IMPLEMENTATION, PARTNERSHIPS AND FUNDING	1-16. Investigate Environmental Contribution to Health Disparities	2-3. Build Community Capacity through Partnerships and Technical Assistance			
	1-17. Partner to Advance Access to Health Care in Communities Experiencing Environmental Inequities				
RESEARCH TRANSLATION AND COMMUNICATION	1-18. Translate Research to Policy Makers	2-4. Communicate Community-Engaged Research			
		2-5. Increase Use of Technology to Communicate and Educate Stakeholders			
RESEARCH EVALUATION		2-6. Promote Environmental Justice Education and Training of the Next Generation of Scientists and Engineers			
	1-19. Evaluate the EPA's Integration of Environmental Justice into Decision-Making			4-1. Assess Research Outputs' Support of Environmental Justice Outcomes	5-3. Assess Effectiveness of Environmental Justice Training for Staff
			4-2. Assess Effectiveness of Stakeholder Partnerships		
			4-3. Assess Use of EPA Tools		

V. Summary

ORD's EJ Research Roadmap is the first documentation of ORD's existing and ongoing research supporting the Agency's implementation of environmental justice. The EJ Roadmap is presented as a summary inventory of ORD's research efforts, categorized by four overlapping EJ science challenges: (1) developing decision-support tools for identifying and prioritizing concerns, assessing cumulative impacts, and evaluating mitigation options; (2) improving our understanding of environmental health disparities and developing methods and data for assessing cumulative risks; (3) supporting Tribal sustainability and well-being; and (4) characterizing climate justice.

ORD research directs attention to the myriad issues raised by environmental justice and captured through discussions with advisory groups like NEJAC, NACEPT, the Institute of Medicine, EPA's own SAB, and ORD's BOSC. Areas for increased emphasis include research that more fully integrates the interactions of the built, natural, and social environments with human biology in determining environmental exposures and outcomes; the equitable distribution and accounting for ecosystem services; further progress on EJ analysis including exposure assessment; the need for expanded social science approaches integrated with the natural and physical sciences; direct engagement with communities in setting research directions; assessing the outcomes of decisions affecting communities and assessing the utility of ORD tools for addressing EJ issues; and building community capacity to engage directly in environmental decision-making.

Appendix A. Environmental Justice-Related Research Projects

The project titles reflect preliminary alignments in the 2016–2019 Strategic Research Action Plans. Programmatic changes could result in project name changes, realignment, mergers, or splits that are not reflected in this table.

Table A-1. ORD Projects including Environmental Justice Research

National Research Program, Project Number	Title
ACE CIVA-3	Climate Change Impacts, Vulnerability and Adaptation: Systems-based Approaches for Sustainable Solutions <ul style="list-style-type: none"> • Integrated response strategies such as combined climate adaptation and mitigation actions with decision-support tools
ACE EM-3	Changing the Paradigm for Air Pollution Monitoring <ul style="list-style-type: none"> • Village Green • Air Sensor Toolbox for Citizen Scientists and low-cost air sensor performance evaluations • RETIGO for data visualization on GIS backdrop and interface with C-FERST, EnviroAtlas • Fugitive, area source, and fence-line monitoring
ACE PEP-1	Local and Regional Characteristics Influencing Public Health Impacts in Healthy and At-risk Populations <ul style="list-style-type: none"> • Near-road, near-port exposures and wildfire health impacts • At-risk populations
ACE PEP-2	Modifiable Factors that Influence Air Pollution-related Public Health Impacts in Healthy and At-risk Populations and Inform Risk Mitigation Strategies <ul style="list-style-type: none"> • Understanding the role of modifiable factors such as diet, exercise, exposure to green space, social stressors in the association between air pollution and environmental public health • Identification of actions that mitigate exposure to air pollution and reduce health effects
ACE PEP-4	Translate Research into Actions that Protect Public Health and Wellbeing <ul style="list-style-type: none"> • Healthy Heart • Wildfire vulnerability index • Environmental literacy
ACE SEM-3	Sustainable Energy and Mitigation: End-use Impacts <ul style="list-style-type: none"> • Cook stoves – health and climate benefits of cleaner technologies
CSS Topic 1	Chemical Evaluation: High Throughput Toxicology, Rapid Exposure, and Dosimetry <ul style="list-style-type: none"> • Contributes data on hazard and exposure potential of chemicals; chemical prioritization for additional testing or risk management
CSS Topic 2	Life-cycle Analytics <ul style="list-style-type: none"> • Providing the tools to evaluate exposure to chemicals across the life cycle of products; assessment of safer alternatives; and emerging materials such as nanomaterials

National Research Program, Project Number	Title
CSS Topic 3	Complex Systems Science: Adverse Outcome Pathway Discovery and Development <ul style="list-style-type: none"> • Developing effect-based methods for assessing cumulative exposures and risks
HHRA-1, -2	Integrated Risk Information System (IRIS) Assessments and Updates <ul style="list-style-type: none"> • Incorporation of susceptibility and vulnerability information
HHRA-4	Provisional Peer-reviewed Toxicity Values <ul style="list-style-type: none"> • Information to make informed decisions about cleaning up contaminated sites to protect human health in nearby communities
HHRA-6	Cumulative Risk Assessment (CRA) Methods and Applications <ul style="list-style-type: none"> • Integrating chemical and nonchemical stressors, including community stressors, impacts of green space, for CRA • Epigenetics: Potential mechanism through which nonchemical stressors increase susceptibility to chemical stressors • Multiple stressor, multimedia research to inform CRAs
HSRP – Remediating Wide Areas	Community environmental resilience to disasters <ul style="list-style-type: none"> • Community Environmental Resilience Index
SHC 1.62	EnviroAtlas <ul style="list-style-type: none"> • Community-scale mapping of access to nature’s benefits with demographic and other population information • Proposed climate change vulnerability information
SHC 1.63	Environmental Workforce and Innovation <ul style="list-style-type: none"> • Greater Research Opportunities fellowships • People, Prosperity, and the Planet (P3) Student Competition for Innovation
SHC 2.62	Community Public Health and Well-being <ul style="list-style-type: none"> • Information access, mapping, and community engagement tools: C-FERST, T-FERST, CCAT • Health impact assessment • Bioavailability and urban soils • Biological (including epigenetic) basis for asthma and other high priority environmental health outcomes in the context of social and neighborhood factors and exposure to pollution • Screening-level models for near-road and near-port contexts • Nonchemical stressors and analytical methods in CRAs including STAR-funded RFA
SHC 2.63	Assessing Health Disparities in Vulnerable Groups <ul style="list-style-type: none"> • Children’s environmental health, including NIEHS-EPA Centers of Excellence with community engagement • Health disparities, including NIH-EPA Centers of Excellence • Epigenetic research into early chemical and nonchemical determinants of later disease or poor birth outcomes • Tribal science, including STAR-funded RFA • Climate change impacts in communities with contaminated sites

National Research Program, Project Number	Title
SHC 2.64	Indicators, Indices, and the Report on the Environment <ul style="list-style-type: none"> • Human and Tribal Well-being Indices • Climate Resilience Screening Index (CSRI)
SHC 3.61	Contaminated Sites and Sediments <ul style="list-style-type: none"> • GIS-mapping and statistical analyses to identify communities and populations disproportionately impacted by climate change-vulnerable contaminated sites • Spatial assessment of contaminated groundwater at hazardous waste sites near vulnerable drinking water supplies • Exposure assessment case study of a community disproportionately impacted by climate-vulnerable contaminated sites
SHC 4.61	Integrated Solutions for Sustainable Communities <ul style="list-style-type: none"> • Integrated ports assessment • Regional Sustainable Environmental Science (RESES); multiple projects on community engagement, health impact assessments (HIAs), ports assessments, sustainability in overburdened communities
SSWR 4.01	Reducing Impacts of Harmful Algal Blooms <ul style="list-style-type: none"> • Health impacts, water availability, Tribal sustainability
SSWR 5.02	Support increased adoption of green infrastructure into community stormwater management plans and watershed sustainability goals: Information and Guidance through Community Partnerships <ul style="list-style-type: none"> • Collaboration on health impact assessment • Decision support for green infrastructure solutions
SSWR 6.03	Water Systems: Transformative approaches and technologies for water systems <ul style="list-style-type: none"> • STAR research on small water systems, including <i>colonias</i> in U.S.-Mexico Border area

Table A-2. STAR Research Addressing Environmental Justice

EPA Office of Research and Development Science to Achieve Results (STAR) grant solicitations and awards that include community-engaged research, research on exposure and health disparities and the contribution of nonchemical stressors or social determinants of health, Tribal sustainability, and engineering solutions for issues in overburdened communities. Hyperlinked locations provide more detail on each of these solicitations.

Title	Research Program	Project/ Topic	Description	Completion Date
Children’s Environmental Health and Disease Prevention Centers Program	SHC	2.63	EPA-NIEHS Children’s Environmental Health and Disease Prevention Centers (joint with NIEHS) (14 currently active). Includes safety of farmworker families and urban asthma research.	2016
Children’s Environmental Health and Disease Prevention Centers Program	SHC	2.63	A Children’s Centers RFA funded in 2015 solicited proposals with increased emphasis on how nonchemical factors and social determinants of disease might exacerbate the risks associated with pollutants, making it especially relevant to health disparities and EJ concerns.	2020
STAR Tribal Research Grants	SHC	2.63	Six grants focused on the development of sustainable solutions to environmental problems that affect Tribes by focusing on (1) health impacts of climate change on Tribal populations, and (2) health impacts of indoor air pollution exposures that derive from or are directly affecting traditional Tribal lifeways and cultural practices with specific emphasis on impacts to vulnerable groups within Tribal communities.	2017–2019
Transdisciplinary Networks of Excellence on the Environment and Health Disparities	SHC	2.63	Ten Centers of Excellence in Health Disparities, Joint with NIMHD through MOU (2012–14) are evaluating how disproportionate environmental exposures, especially in air and water, in combination with a diverse array of nonchemical factors including social (including racial/ethnic composition), built environment (such as poor housing, access to recreation facilities), lifestyle (such as smoking), and economic stressors (such as lack of access to healthy food) contribute to health disparities. A variety of negative health outcomes is considered including cardiovascular disease, diabetes, poor mental health, and cancer. Some centers are using geospatial and temporal analyses to examine relationships and syndemic effects among health disparities and environmental factors. Emphasis in others is placed on community-based outreach and interventions.	2014

Title	Research Program	Project/ Topic	Description	Completion Date
NIH-EPA Centers of Excellence in Health Disparities	SHC	2.63	A new cross-agency STAR RFA (2014) created in partnership with NIH (NIEHS, NIMHD, and NICHD) will fund Centers of Excellence in Health Disparities to stimulate basic and applied research to understand environmentally driven health disparities and improve access to healthy environments for vulnerable populations and communities. It is designed to foster interdisciplinary research on the complex interactions between social, natural, and built environmental systems, conditions, and policies that result in unequal environmental health conditions and disproportionate impacts among (diverse) disadvantaged population groups, communities, neighborhoods, and individuals. Outcomes of this research are expected to promote innovative approaches and strategies to mitigate environmentally driven exposures and health disparities, alleviate system drivers of racial/ethnic and socioeconomic disparities, and improve access to healthy and sustainable environments for vulnerable populations. Proposals must include community-based research, mentoring, capacity building, and research translation and information dissemination. (Centers to be funded in late 2015.)	2020
STAR RFA on Understanding the Role of Nonchemical Stressors and Developing Analytic Methods for CRAs	SHC	2.62	This includes grants on Community-based Participatory Research to Develop New Methods for Analysis of Cumulative Risk in Urban Populations; Effects-based CRA in a Low-Income Urban Community near a Superfund Site; Effects of Stress and Traffic Pollutants on Childhood Asthma in an Urban Community; Hypertension in Mexican-Americans: Assessing Disparities in Air Pollutant Risks; Combined Effects of Metals and Stress on Central Nervous System Function.	2014–2016
STAR P3 Grants	SHC	1.63	Innovation small grants to universities; these address STEM education goals and specific research goals. Grantees include: DePaul University – Community-based Soil Quality Assessment as a Tool for Designing an Urban Green Infrastructure Network to Manage Runoff; University of California – Davis Small-Scale Ecosystem Engineering: Development of Household-Level Graywater Treatment Systems; Mississippi State University – User-Friendly Design Tools for Sustainable Wastewater Treatment in Rural and Disadvantaged Communities.	Annual Competition

Title	Research Program	Project/ Topic	Description	Completion Date
STAR Grants on Small Water Systems	SSWR	Water Systems, Project 3	These include a grant to a consortium of three Missouri universities, led by Lincoln University of Missouri, a historically black college and university, to identify trihalomethanes and N-nitrosamines associated with elevated dissolved organic carbon/dissolved organic nitrogen in surface water supplies, and develop and implement water treatment technologies to reduce the health threats; point-of-use water treatment systems for improving sustainability and environmental justice in the Paso del Norte Region; a grant for small systems and Native American communities to develop, test, and demonstrate small drinking water treatment methods to remove common groundwater constituents in extreme environments using readily available materials, such as biochar.	2015–2017
Water Infrastructure Sustainability and Health in Alabama’s Black Belt	SSWR	Water Systems, Project 3	This STAR grant is designed to examine water and health in the “black belt” of Alabama. This is a region where a large population of people of color resides that is historically and currently underserved and economically disadvantaged. The grantees are conducting a prospective cohort study that follows 900 households for 18 months and includes active surveillance of household water quality and health outcomes. Researchers are working with residents in rural Hale, Wilcox, and Sumter counties in Alabama.	2015
Air Pollution Monitoring for Communities (to be awarded)	ACE	PEP	This solicitation seeks research on (1) empowering communities and individuals to take action to avoid air pollution exposure using low-cost portable air pollution sensors; (2) ways communities and individuals interact with air pollution sensors and their data; (3) methods for understanding and managing the quality of data from air pollution sensors; and (4) how sensors and sensor networks compare to traditional air quality monitoring methods. Given the potential for portable air pollution sensors to enable communities to reduce exposure and risk, substantial engagement with community groups is encouraged. Research that will advance the ability of communities and individuals to take action to avoid air pollution exposure is of particular interest.	2019

Title	Research Program	Project/ Topic	Description	Completion Date
Experimental Interventions to Facilitate Clean Cook Stove Adoption, Promote Clean Indoor Air, and Mitigate Climate Change	ACE	SEM	<p>This study will use price and social interaction experiments to provide valuable information about technical and behavioral dimensions of stove adoption and use. Climate modeling will provide a realistic assessment of the range and timeframe of foreseeable climate benefits resulting from widespread stove adoption. The project builds on preexisting partnerships with two Indian NGOs already promoting stoves in rural communities to take advantage of existing connections to stove-using households in diverse parts of India. Both NGOs are well established and well staffed with gender- and caste-sensitive personnel who will facilitate entry into the complex social terrain of rural India.</p>	2016
A Nontargeted Method for Measuring Multiple Chemical Exposures among a Demographically Diverse Population of Pregnant Women in Northern CA	CSS	Topic 1	<p>This grant will use enhanced biomonitoring methods to characterize chemicals found in a racially diverse cohort of pregnant women. The results should show (1) whether pregnant women are exposed to more environmental organic acids than previously understood, (2) whether there are racial or ethnic differences in exposures, and (3) whether there are correlates with socioeconomic status.</p>	2014

Appendix B. ORD's 16 Making a Visible Difference Communities

*The efforts described below are in various stages of development; some are more formative than others.

Region 1

- **Lawrence, MA** – ORD will provide expertise and tools to Region 1 and local communities to help develop strategic water plans and green infrastructure for better combined sewer overflow control, water quality compliance, and evaluate and improve drinking water supply resilience for residents' wellbeing.
- **Bridgeport, CT** – ORD will provide expertise, data, and tools to Region 1 and local communities for climate vulnerability assessment and adaptation planning of wastewater infrastructure.

Region 2

- **Newark, NJ** – The MVD project for Newark will include data and approaches from the EPA Region, ORD, local community groups, and potentially State and other agencies. Plans are to form a collaborative partnership to leverage expertise and problem-solving experience to improve local resiliency and to develop risk reduction actions.

Region 3

- **Newport News, VA** – ORD will support Region 3 in conducting a CRA associated with the port of Hampton Roads, VA.
ORD is also working with Region 3 in the Newport News/Norfolk area as part of the Rockefeller 100 Resilient Cities initiative.
- **Dover, DE** – C-FERST is being used in applying the successful approach from Region 10, doing community outreach and engagement, partnering with local community colleges and universities, and translating success in Region 10 to other communities.

Region 4

- **N. Birmingham, AL** – There are two portions to this Regional Sustainable and Environmental Science (RESES, ORD-based competitive funding for collaborative projects) project: an EnviroAtlas portion and a National Stormwater Calculator portion. ORD will collaborate with the City of Birmingham and Jefferson County to obtain and input the county's LiDAR data into the Community Component of EnviroAtlas to provide high-resolution data on ecosystem services and community benefits specific to Birmingham. The City will use the results of the EnviroAtlas analysis in their green infrastructure planning processes to gain a better understanding of how its decisions can affect ecological and human health outcomes. The second portion is to add a costing module to the National Stormwater Calculator to assist the City in determining the costs of various stormwater control measures. Originally, it was hoped that the RESES project would allow the City to compare green and gray infrastructure options and develop a web application for the National Stormwater Calculator, but resources are insufficient to accomplish this goal. These two functions will be considered for later projects.

- **Proctor Creek, Atlanta, GA** – This project entails a green infrastructure HIA for the entire Proctor Creek Watershed.

Region 5

- **Mill Creek, Cincinnati, OH** – The City of Cincinnati has already undergone a great deal of transformation with regard to stormwater and developing a more sustainable community. In 2013, for example, they received approval from EPA to cancel their plans to build a 40-million gallon tunnel in lieu of storm sewer separation and green infrastructure projects to reduce stormwater entering the combined sewer system.

EPA scientists are collecting hydrology and water quality data at a large Cincinnati green infrastructure project at St. Francis Apartments where a two-tiered parking lot has been converted to extensive rain gardens. ORD has already provided pollutant concentration data into and from the rain gardens to Cincinnati's Municipal Sewer District to help inform its estimates of pollutant load changes associated with green infrastructure. A report presenting and interpreting the full data set from St. Francis will be completed as a final product of this study and share with the District and Region 5.

In addition to the St. Francis pilot study, ORD will contribute to a new pilot effort led by Hamilton County to develop an incentive program for green infrastructure (rain barrels, rain gardens) on private homeowner properties in the Kings Run area. Information from the previous ORD Shepherd Creek study has already informed its current Kings Run proposal, and ORD will continue to provide technical support and information as helpful to the process. For example, new estimates of life-cycle costs of the rain gardens and rain barrels from the Shepherd Creek study are being developed. This information will be shared with Hamilton County and the District to inform their Kings Run planning process.

- **Milwaukee, WI** – ORD is supporting the use of EnviroAtlas for community-scale data. EnviroAtlas is a collection of interactive tools and resources that allows users to explore the many benefits people receive from nature, often referred to as ecosystem services. Although critically important to human well-being, ecosystem services are often overlooked. Using EnviroAtlas, many types of users can access, view, and analyze diverse information to better understand how various decisions can affect an array of ecological and human health outcomes.
- **SE Chicago, IL** – This project was recently added to the ORD list and includes a Regional Applied Research Efforts grant for a Village Green station at a public elementary school and educational outreach with those students.

Region 6

- **Alexandria/Pineville, LA** – ORD is working with Regional staff to enhance a sustainability assessment to help local wood-preserving operations to use sustainable materials management approaches, perform groundwater plume delineation, and review ambient and property line air monitoring data.

- **Crossett, AR** – ORD is supporting a CRA of paper plant-related pollution rippling through urban environment and fish consumption.

Region 7

- **Omaha, NE** – The City of Omaha has demonstrated that a hybridized system utilizing both green and gray infrastructure methods with the goal of reducing sewer overflows is the most efficient and cost-effective approach to managing stormwater runoff. Specifically, the city is demonstrating the utility from investigating soil properties (take strategic soil core samples) prior to designing an infiltration-based green infrastructure technology for a specific area, plot, or property. Between 2012 and 2014, a demonstration took place at 16 study sites throughout Omaha. This approach has been used to confirm and otherwise direct proper application and location of the green infrastructure techniques at 23 sites in Omaha. Documentation and outreach materials describing these practices and results have been prepared and are being used by stakeholders. A collaborative relationship between the Omaha public works, Nebraska Department of Environmental Quality, University of Nebraska, USGS, EPA Region 7, and ORD have contributed to understanding green infrastructure and ultimately to support the city’s combined sewer overflow long-term plan, which has direct impact on the community.

Additionally, a demonstration green infrastructure project was selected by the City of Omaha to investigate and track through FY2017 the long-term performance and natural dynamic properties of a specific site. ORD and R7 are collaborating with USGS’s Nebraska Water Science Center developing, implementing, and documenting a monitoring strategy for showcasing environmental and economic efficiencies of green infrastructure for stormwater overflows. An EPA kiosk is set up at the University of Nebraska, Omaha Extension. The kiosk is a communication tool between EPA and the community to relay up-to-date information about the project and provide a resource for understanding green infrastructure technologies.
- This MVD project will showcase the approach of designing and monitoring a green infrastructure project from up to 23 different sites in the Omaha community.

Region 8

- **Sun Valley, Denver, CO** – This project entails a systems assessment of and recommendations for the Sun Valley neighborhood around the light rail station. The goals for the neighborhood are to improve connectivity, vibrancy, and economic opportunities, while maintaining cultural diversity and a sense of place. ORD will use experience gained from the Durham, NC light rail study.

Region 9

- **Imperial Valley, CA** – ORD will contribute expertise (and possibly loaned equipment) to Imperial Valley for air monitoring, with data communication and application.
- Region 9 is looking to enhance an existing community air quality research study, which involves distributing approximately 30 low-cost particulate matter air monitors that report real-time concentrations and do live-reporting of the data to the public. This existing study could be strengthened in multiple different ways to have greater impact. Region 9 and ORD have had

multiple discussions on approaches to enhance the existing project and provide support to the community.

Region 10

- **N/NE Portland, OR** – ORD is providing holistic support for community needs—land use, brownfields, urban waters, air, equity in development.
 - Awarded RESES (Regional Sustainable and Environmental Science): Making a Visible Difference in N/NE Portland: Engaging Communities; Using Citizen Science to Assess and Address Children’s Environmental Health from Transit and Air Pollution

Appendix C. Acronyms and Abbreviations

ACE	Air, Climate, and Energy research program, ORD, US EPA
BOSC	Board of Scientific Counselors – FACA group for Office of Research and Development, US EPA
CCAT	Community Cumulative Assessment Tool
CERI	Community Environmental Resilience Index
C-FERST	Community-focused Exposure and Risk Screening Tool
CHPAC	Children’s Health Protection Advisory Council – FACA group for Office of Children’s Health Protection, US EPA
C-LINE	Community Line – source screening-level model to estimate air quality near roadways or other “line” sources based on emissions inventories, meteorological data, and analytical models of air dispersion
C-PORT	Community Port screening-level model to estimate air quality from line, point, and area sources in port locations based on emissions inventories, meteorological data, and analytical models of air dispersion
CRA	cumulative risk assessment
CRSI	Climate Resilience Screening Index
CSS	Chemical Safety for Sustainability research program, ORD, US EPA
EJ	environmental justice
EO	Executive (Presidential) Order
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act of 1972
GIS	geographic information system
HHRA	Human Health Risk Assessment research program, ORD, US EPA
HIA	health impact assessment
HSRP	Homeland Security Research Program, ORD, US EPA
IRIS	Integrated Risk Information System, HHRA / NCEA, ORD, US EPA
ISA	Integrated Science Assessment of NAAQS pollutants
LEO	Local Environmental Observer
MVD	Making a Visible Difference implementation plan for EPA crosscutting strategic goal
NAAQS	National Ambient Air Quality Standards
NACEPT	National Advisory Council on Environmental Policy and Technology
NCEA	National Center for Environmental Assessment, ORD, US EPA
NCVHS	National Committee on Vital and Health Statistics
NEJAC	National Environmental Justice Advisory Council
NICHD	National Institute of Children’s Health and Human Development, one of the NIH
NIEHS	National Institute of Environmental Health Science, one of the NIH
NIH	National Institutes of Health
NIMHD	National Institute of Minority Health and Health Disparities, one of the NIH
ORD	Office of Research and Development, US EPA
PCB	polychlorinated biphenyl organic chemical compound
PEP	Protecting Environmental Public Health project in ACE program, ORD, US EPA
PFC	proper functioning condition – method for evaluation of ecological condition
RESES	Regional Sustainable Environmental Science awards funding (internal to EPA) for ORD-Regional collaborative projects, SHC, ORD, US EPA

RETIGO	Real-Time Geospatial Data Viewer
RFA	Requests for Applications for grant solicitations
SAB	Science Advisory Board FACA for US EPA
SHC	Sustainable and Healthy Communities research program, ORD, US EPA
SSWR	Safe and Sustainable Water Resources research program, ORD, US EPA
STAR	Science to Achieve Results granting program, ORD, US EPA
StRAP	Strategic Research Action Plan (for each of ORD's National Research Programs)
T-FERST	Tribal-focused Environmental Risk and Sustainability Tool
USGS	U.S. Geological Survey

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